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Assessing Landscape Change in Western Honduras, 1957-2010

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ASSESSING LANDSCAPE CHANGE IN WESTERN HONDURAS, 1957–2010

by

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ABSTRACT

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Human impacts on environmental conditions have long concerned researchers investigating changing forest conditions in the world's tropical regions. This thesis uses repeat photography, satellite imagery, and quantitative spatial statistics to evaluate landscape change in western Honduras between 1957 and 2010, and specifically focuses on changes in tree cover. Results from repeat photography and satellite classification show an increase in tree cover. Spatial statistics indicate that increases in shade coffee production may also be related to much of the observed increases in tree cover. Forest transition theory is used as a framework to help explain the observed changes, such as dooryard gardens, trees among settlements, fence rows, and small reforested and afforested areas.

ACKNOWLEDGMENTS

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LIST OF ABBREVIATIONS

COHDEFOR .... Honduran Forestry Development Corporation

ERDAS ....Earth Resource Data Analysis System

GIS .... Geographic Information System

IHCAFE...Honduran Coffee Institute

USGS .... United States Geological Survey

CHAPTER I

INTRODUCTION

Around the world people use the Earth's surface as a palette on which to create places to live and interact. These spaces consist of buildings, roads, signs, lawns, forests, parks, and the list could go on. Collectively, these spaces make up cultural landscapes – mosaics of material culture that represent the occupancy and activity of people across space and time. Indeed, most landscapes are inherently cultural. Urban areas are easily recognized as cultural landscapes due to the myriad of material culture that can be seen in them. Nonetheless, rural areas – made up of forests, pastures, and other aspects of rural life – are also cultural landscapes. Landscapes are constantly subject to change as people decide to use the land in various ways. For example, a pasture might turn to forest, or a vacant lot might become occupied. Landscape changes occur at various spatial and temporal scales, and are driven by complex social, political, and economic factors.

Landscape change and forest conditions are a topic of concern around the world. Tropical deforestation is a well-known and documented type of landscape change (Hiraoka 1980; Moran 1993; Stonich and DeWalt 1996). Less recognized are cases of forest recovery and tree expansion. However, a growing body of research suggests that some tropical landscapes are undergoing forest recovery, particularly at local scales (Hecht et al. 2006; Bass 2006). Many complex variables and processes have been found to influence such recoveries in developing areas around the world. These include, but are not limited to economic development, government policies, and conservation management and ideals. Forest transition theory has been used as a model to understand these influential variables and processes. Generally, it suggests that economic opportunities will draw rural populations to urban centers, allowing previously cultivated rural land to transition into forest (Mather 1992). The dialogue surrounding forest transition was once based on patterns that occurred in the U.S. and Europe. In these areas, transition occurred under economic, political, and social circumstances and pressures different than those currently faced by developing nations. Today, globalization heavily influences many developing areas, and contributes to changing economies, politics, and social structure. These factors can lead to changes on the land. Forest transition discourse has expanded to encompass new ideas that seek to understand how forest transitions might occur in developing nations today amid increasingly complex variables, many of which are associated with globalization.

Over the past decade, researchers have discovered increasing amounts of forests and small tree patches in Honduras (Southworth and Tucker 2001; Bass 2004, 2006). Small tree patches are common in Honduras and may range from a couple of trees to woodlots of a few hectares. Many of these patches are too small to be called forests. However, their importance remains. Landscapes characterized by tree cover expansion are appearing for reasons that are not well understood. Some believe that shade-coffee cultivation is playing an important role in forest recovery in parts of Honduras (Bass 2006).

In recent years, coffee cultivation has expanded in areas of Honduras due to increased participation in international markets. Because the majority of coffee varieties grown in Honduras are shade-loving, farmers keep and/or plant trees that provide the forest canopy necessary for these coffee plants. This is one theory to explain why more forests are appearing on parts of the Honduran landscape. Certainly, other factors are also contributors. Tree patches could be appearing as rural people keep agricultural land in fallow for a long period of time, or grow trees to use for lumber and cooking fuel.

This study, conducted during the summer of 2010, uses two methods to look at landscape conditions in western Honduras. First, repeat photography is used to examine patterns of landscape change between 1957 and 2010, specifically with an interest in recognizing tree cover expansion. These findings are placed within a current forest transition framework to better understand what might be driving the observed conditions. Secondly, satellite image and statistical analyses are conducted with an expectation of better understanding the relationship between coffee and forested landscapes in western Honduras. While a full understanding of the political and economic variables involved in forest transition lies outside the scope of this research, this study will contribute to an emerging discourse that relies upon repeat photography to analyze landscape change in the developing world and provide yet another example of what forest transitions may look like in the 21st century.

CHAPTER II

CONCEPTUAL FRAMEWORK

Human-Environment Interactions

In geography, there has been a long tradition of studying how people interact with nature. One way that geographers do this is by studying the landscape. This approach arose in the 1920s at the hand of Carl O. Sauer (Sauer 1925). Sauer was interested not only in anthropogenic environments (those that have been altered by people), but also the origin of the techniques used to implement changes, such as fire (Sauer 1950). He and others studied these environments by interpreting prehistoric, historic, and contemporary cultural landscapes (Sauer 1950; Parsons 1955; Johannessen 1963). Many times, this meant thoroughly investigating vegetation regimes to distinguish those that were natural from those that were cultural.

Cultural and political ecology represent contemporary extensions of this human-environment tradition. Like Sauer's emphasis, they also center their studies in the rural developing world. Cultural ecology often demonstrates how landscapes are created and change over time, whereas political ecology seeks causative factors. Developed in the 1960s through the convergence of the Sauerian tradition and ideas coming from cultural anthropology, cultural ecology sought to uncover processes behind human-environment interactions. These processes are seen as inherently cultural. That is, certain cultures have particular relationships with the environment, such as specific agricultural and resource use techniques.

To better understand these relationships cultural ecologists take two main approaches. One views people as a single component functioning in a larger system.

Similar to an ecosystem, in this viewpoint humans are another entity through which nutrients and energy flow. Understanding these flows can help understand why some societies interact with the environment in certain ways. For example, a small subsistence society will grow a certain number of calories in agricultural plots. Some crops contain more calories than others, requiring less land area to produce the same number of calories. So in an ecosystem approach, understanding caloric flows helps understand why people make the decision to grow one crop over another. The other approach concentrates on land use strategies that people implement to maintain their everyday needs. These strategies – implemented both consciously and subconsciously – inevitably impact the environment. Both of these approaches have typically been used to study traditional or indigenous societies – past and present – in the rural developing world.

While it is true that certain environmental relationships are learned through culture, it is also true that government policies and economics influence these relationships. From this idea came the field of political ecology, an interdisciplinary calling that concentrates on how politics and economics may prompt people to choose a particular land use strategy. Notably, these policies and economies operate across multiple scales (global, regional, and local). A general assumption among political ecologists is that global and regional level forces often impact human-environment relationships at local levels (Zimmerer 1996). The line that separates cultural from political ecology can often be blurry, as many of their concepts overlap.

Although landscape is not always an explicit topic in these two subfields, their literature can help better understand landscape dynamics. Because cultural and political ecology generally look in depth at specific human-environment relationships, reviewing their literature can help understand complex social arrangements that create certain landscapes; arrangements that include subsistence and livelihood practices, conservation, rituals and beliefs, government policies, and market factors. Many times, these are intertwined, creating complex stories behind patterns that are seen on the land.

In the rural developing world, subsistence landscapes often dominate the field-of-view. In the mountains of western Honduras, agricultural plots, pasture, woodlots, along with small homes nestled therein, provide people with food, income, building materials, cooking fuel, and shelter. Around the world, societies engage in a variety of land use strategies to provide themselves with the things that they want and need. Since prehistoric times people have constructed agricultural landscapes including terraces, raised fields, drained fields, swidden plots, and others with varying degrees of complexity (Parsons and Denevan 1967; Mathewson 1984; Denevan 1992). These different agricultural systems developed as ways for people to support their populations in conducive environments.

Slash-and-burn agriculture (sometimes called swidden or shifting cultivation) is a type commonly practiced by many people in tropical regions around the world. In this system, most trees are cleared from a plot of land, and once dry they are burned. This provides the soil with nutrients needed for a successful growing season. Ideally, a single plot would be used for a single growing season, after which the soil becomes leached of nutrients, and the farmer shifts to a new forested plot to start the process again. After a used plot lies fallow for several years it recovers to the point where it can be used again.

The slash-and-burn method has been praised for its high levels of biodiversity, which is believed to lead to a more stable and sustainable system than that of industrial monoculture systems (Geertz 1963; Rappaport 1971). Its ability to hold up to population pressure has been called to question (Geertz 1963; Brookfield 1972; Turner et al. 1977). Still, it has been found to be a sustainable agricultural system in terms of conservation management (Cochran 2005). Although one argument holds that increases in human population density can lead to shortening of fallow cycles and a rise in the number of plots in production (Turner et al. 1977). The resulting environmental changes might include soil degradation and more forested land converted to agriculture. Moreover, sustaining slash-and-burn agricultural systems may be dependent on how well they can compete with other cash market activities, as subsistence activities often give way to cash making opportunities (Cochran 2008).

Growing population density is not the sole culprit of shifts in land use. Agriculture and other land use systems are often influenced by unique combinations of subsistence, rituals and beliefs, economic and political, and a myriad of other motivators. Even the smallest rural settlements can be affected by globalization (the global exchange of information, ideas, currency). In the 21st century most rural communities in the developing world are affected to varying degrees by forces well beyond their community boundaries. People in these areas are motivated to use the land in particular ways by national and international nongovernmental organizations (NGOs) (Sundberg 2003), government policies (Robbins 2003), engagement in market-based activities (Grossman 1993), and conservation ethics (Schelhas and Pfeffer 2008; Tucker 2008). Notably, land use often depends on who has access to and control over land and resources (Hecht and Cockburn 1989; Stonich 1993; Robbins 1998; Jansen 1998).

In the 1970s the Honduran government nationalized all forest resources, providing one example of how governments can influence and control land use. Under the nationalized system land continued to be privately or communally held, however, the forests belonged to the state and were managed by the Honduran Forestry Development Corporation (COHDEFOR). Tucker (2008) describes how nationalization of the forestry sector affected people in the rural town of La Campa. As residents lost control over forest management rights, they also lost the right to oversee quantities of forest extraction. In turn, residents were suspicious of over-extraction and being uncompensated for timber coming from their land (ibid). Further, in an attempt to protect their forest resources the Honduran government targeted slash-and-burn agriculture, claiming (possibly falsely) the technique was responsible for the majority of forest fires. COHDEFOR required people to obtain permits to cultivate, burn, or clear land for houses. However, through collective action the people of La Campa were eventually able to reassume control over their forest resources (ibid). As landscapes are influenced by such complex forces, interpreting them often requires more knowledge than one can gather from simply looking.

Just as national governments and economics can influence resource management and landscape conditions, so can international forces. Many national governments establish international trade agreements, which, in the developing world often translate to the creation of larger markets for certain land-based goods (agricultural crops, livestock, forest products, and energy related resources). Large-scale banana production in Central America and the Caribbean is driven by international markets (Parsons 1955; Grossman 1993). The same can be said for coffee, and countless other agricultural products.

Recently, rapid landscape change has taken place in various ecosystems in South America as soybean production has claimed thousands of hectares of rainforest, dry forests, and grasslands (Grau and Aide 2008). On the other hand, globalization has also fostered more subtle landscape changes, like those brought on by the introduction of fertilizers and pesticides to rural farmers (Tucker 2008). These inputs allow them to repeatedly cultivate the same garden plot, and in some cases curb reliance on slash-and-burn techniques.

Not unrelated to government and economic influences are those coming from non-governmental organizations. Currently, thousands of NGOs are working on an array of projects in developing nations worldwide, including Honduras (Inter-Hemispheric Education Resource Center 1988). These organizations have the ability to influence societal structure and function, and therefore can influence human-environment relationships in the areas they work. Sundberg (2003) illustrates how NGOs working in the Maya Biosphere Reserve in Guatemala influenced the way local residents think about and act toward environmental issues through involvement in local environmental discourse. She argues that NGOs can construct "truths" pertaining to human-environment relationships, and thus can have power to influence local people's perceptions and beliefs on conservation (Sundberg 2003). NGOs can also be directly involved in conservation and resource management, assuming roles that governments would often play. NGO Aldea Global illustrates this role as it is responsible for managing Honduras' Cerro Azul Meámbar National Park (Schelhas and Pfeffer 2008).

Conservation in the form of large set asides (such as national parks) has been problematic in under-developed countries because many people continue to rely heavily on the land to live (Neumann 1997). To combat this, conservation schemes that incorporate multiple land-use zones within reserved areas have been implemented. Buffer zones are areas designated around the edge of the park to accommodate the livelihoods of local people, while the core area is off limits to such usage. The success of this approach could depend on population density near the land reserve and other place-specific environmental factors (Pfeffer et al. 2005).

Forest Transitions

It is evident that landscape changes in the developing world are influenced by the interplay of a variety of complex variables. Deforestation in one such change, and has often dominated landscape change discourse over the past few decades. The environmental and sociocultural problems associated with it are recognized by researchers and policy makers, though understanding drivers of change is remarkably complex (Hiraoka 1980, 1982; Hecht 1990; Klooster 2000; Godoy 2001; Zimmerer 2004). More recently, researchers have discovered recovering forests in developing nations (Southworth and Tucker 2001; Bass 2006; Hecht 2006; Xu et al. 2007). That leads to the question, could some countries be undergoing 'forest transitions'?

Forest transition theory suggests that, as regions become developed, rural populations are drawn to urban centers for opportunity in various economic sectors (Mather 1992). Increased access to industrial technologies allows agriculture to be concentrated and intensified on the most arable lands, which leaves marginal rural areas to secondary forest succession (ibid). In theory, net forest loss is eventually replaced by net increases. Some historical examples illustrating this trend include the U.S., France, and Denmark (ibid). In these countries, population trends and resource perceptions are considered to be major factors to forest transition. As population increased, agricultural land increased to meet demand. Consequently, forests diminished (Figure 1). As population leveled off and agricultural technology improved, pressure on the land decreased (ibid). This combined with rural-to-urban migration, new environmental policies, and changing attitudes toward the environment is believed to have led to a forest transition (ibid) (Figure 1). Since the formation of Mather's (1992) forest transition theory, other researchers have used it as a framework, built upon it, and debated its applicability to the modern developing world (Rudel 1998, 2006; Rudel et al. 2002; Klooster 2003; Farley 2010).

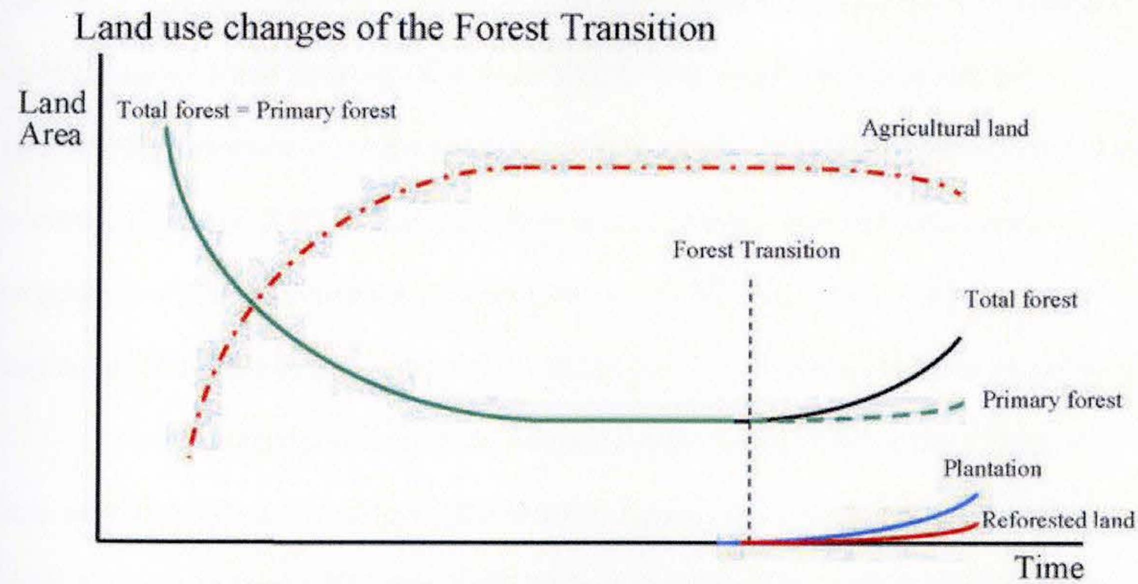


Figure 1. Forest Transition Diagram. Forest transition theories have suggested that as population and agricultural land increase, forested land decreases. This phenomenon occurs in the early stages of a countries formation. Eventually, population levels off, agricultural technologies increase, and economic development occurs. People move to urban areas, and agriculture is concentrated on the most well suited lands. This leaves some areas to reforestation (shown in red). Trees are planted for household use or to be sold as lumber (shown in blue). The hashed vertical line marks the point of forest transition, where forests are recovering faster than deforestation is occurring. (Figure from Barbier et al. 2010, p. 99)

Undoubtedly, the variables that influence forest recovery change through time. Today, forest transitions are likely to take place differently than they have historically (Klooster 2003; Kull et al. 2007). As population density, global and local economies, and conservation policies and ideologies change, so do land use and environmental conditions (Sandoval 2000; Pfeffer et al. 2005). The growing influence of globalization on rural economies, and consequently, forest conditions has been well documented (Hecht 1992, 2006; Moran 1993; Anderson 1995; Evans 1999; Godoy 2001; Doolittle et al. 2002; Zimmerer and Carter 2002; Rudel 2006; Hecht and Saatchi 2007; Tucker 2007; Grau and Aide 2008). Forest transitions are taking place amid complex social interactions. Neoliberal economic reforms around the globe have influenced forest cover by creating shifts to market-based land-use (Kull et al. 2007). This could mean increases in agricultural production or market-based promotion of conservation (commonly related to tourism) (Kull et al. 2007). In addition to economic reforms, transnational labor migration can also influence forest conditions. As Hecht et al. (2006) point out, labor migrations and subsequent remittances could play a role in forest recovery in El Salvador.

Tropical forest transitions occur across a range of geographic scales. They have been explored at the national level (Hecht 2007; Lambin and Meyfroidt 2010), as well as local and regional levels (Klooster 2003; Redo et al. 2009; Farley 2010). Hecht (2009) offers a new perspective on the dynamics of forest cover change that recognizes the importance of woodland resurgence at small scales and the importance of anthropogenic forest types. Hecht (2009) the distinction between the anthropogenic tree patches occurring on the land and pristine forests that are the focus of much ecological research but are not often seen resurging. Kupfer et al. (2006) recognize the potential for these mosaic-like anthropogenic landscapes to harbor biodiversity and sustain viable biotic populations.

In Honduras, landscape changes are taking place due to a variety of social factors (Stonich and DeWalt 1996; Sandoval 2000; Pfeffer et al. 2005; Cochran 2008). These factors lead to sometimes intriguing patterns, such as the increases in forest, at a relatively local scale, found by Bass (2006) and Southworth and Tucker (2001). In the region, forest change and land use, as well as their drivers have been studied extensively (Johannessen 1963; Jansen 1998; Bass 2004, 2006; Brady 2002, 2009; Southworth et al. 2002, 2004; Pfeffer et al. 2005; Tucker 2008). Similar to other developing nations, landscape change in Honduras is occurring as complex global, regional, and local drivers become enmeshed. More trees and forests are appearing at the hand of conservation and related ethics (Pfeffer et al. 2005; Schelhas 2008), economic variables (Munroe et al. 2002; Bass 2006), government policies (Southworth and Tucker 2001; Tucker 2008), as well as through shifts in subsistence and livelihood practices (Brady 2001, 2009; Bass 2004; Tucker 2008).

This study will contribute to understandings of contemporary processes of cultural and environmental landscape change in western Honduras. Complementary methods will assess and offer insights on patterns and drivers of contemporary landscape conditions with the goal of recognizing potential avenues to forest transition.

CHAPTER III

STUDY AREA

The highlands of western Honduras make up the study area for this research. With the exception of a single repeat photograph taken in the department of Lempira, this research – repeat photographs and land use data – is based in the departments of Intibucá and La Paz (Figure 2). Within these two departments are 36 administrative subdivisions, known as *municipios* – seventeen are in Intibucá and nineteen are in La Paz. Population density in the study area is around 70–75 people per kilometer squared (Atlas Geográfico de Honduras 2009). Outside of the larger towns much of the population lives in rural hamlets called *aldeas* (Figure 3). These hamlets are primarily comprised of people of *Lenca* ancestry, an indigenous group that has occupied parts of the region since pre-Columbian times (West 1998), and whose population numbers around 300, 500 (Atlas Geográfico de Honduras 2009). The population in market towns (larger towns where rural residents bring surplus crops to sale on certain days) is comprised of both Lenca and Ladino people (mixed European/indigenous ancestry) (ibid). Many of the people are engaged in subsistence activities, such as swidden cultivation and cattle husbandry, but some also depend on cash crop production, commercial forestry, and emigrant remittances for income (Brady 2001).

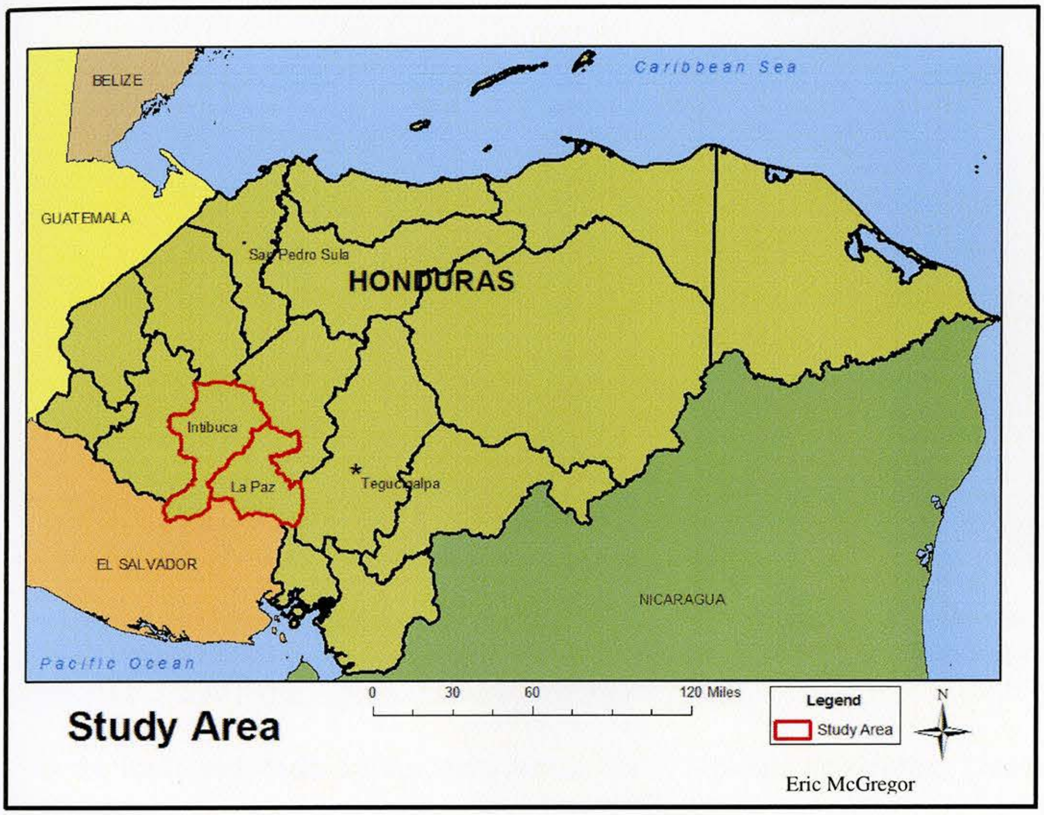


Figure 2. Map showing study area (Intibucá and La Paz) outlined in red.

Figure 3. An *aldea* (rural hamlet) in Azacualpa, Intibucá, Honduras. Also notice the *milpas* (agricultural plots) in the foreground and on surrounding hill slopes with trees growing in and around them. (Photo taken by author)

In the study area, most precipitation is received in June and September. However, amounts of precipitation differ by altitude. Areas below 1500 meters elevation have a distinct dry season that ranges from December to February (Atlas Geográphico de Honduras 2009). These areas receive about 500–1200mm annually (ibid). At higher elevations, January through March is the driest time of year, although these areas do not experience a distinct dry season. Precipitation ranges from 1200–2000mm (ibid). These elevations experience cooler temperatures and dense fog.

Geologically, the study area is primarily encompassed by the Padre Miguel Group. This group consists of igneous, volcanic rocks, such as rhyolite and andesite, as well as their sedimentary derivatives (Atlas Geográphico de Honduras 2009).

Figure 4. A *chagüite* in Santa Elena, La Paz, Honduras. *Chagüites* are saturated highland valleys that typically provide fodder for livestock.

The highlands of Intibucá and La Paz, like much of western Honduras, are characterized by steep mountain terrain. On these steep slopes, forests and agriculture are often intermeshed to make up a landscape resembling a patchwork quilt. Saturated highland valleys (*chagüites*) covered with grass are also characteristic of the region at elevations between 1200 and 1800 meters, and often provide fodder for cattle (Figure 4) (Bass 2010). Typical of other mountainous environments, land cover varies along an altitudinal gradient. Pine species often dominate poor soils found in areas below 1700 meters. *Pinus ocarpa* (or ocote pine) is the most abundant in this altitudinal zone. In the *tierra fresca* (or 'cool land'), above 1700 meters, mixed pine-broadleaf forest can be found, and contain various pine (*P. oocarpa, P. pseudostrobus*) and oak (*Quercus* spp.) species. Above 2000 meters broadleaf cloud forests occur (Figure 5) (Brady 2001).

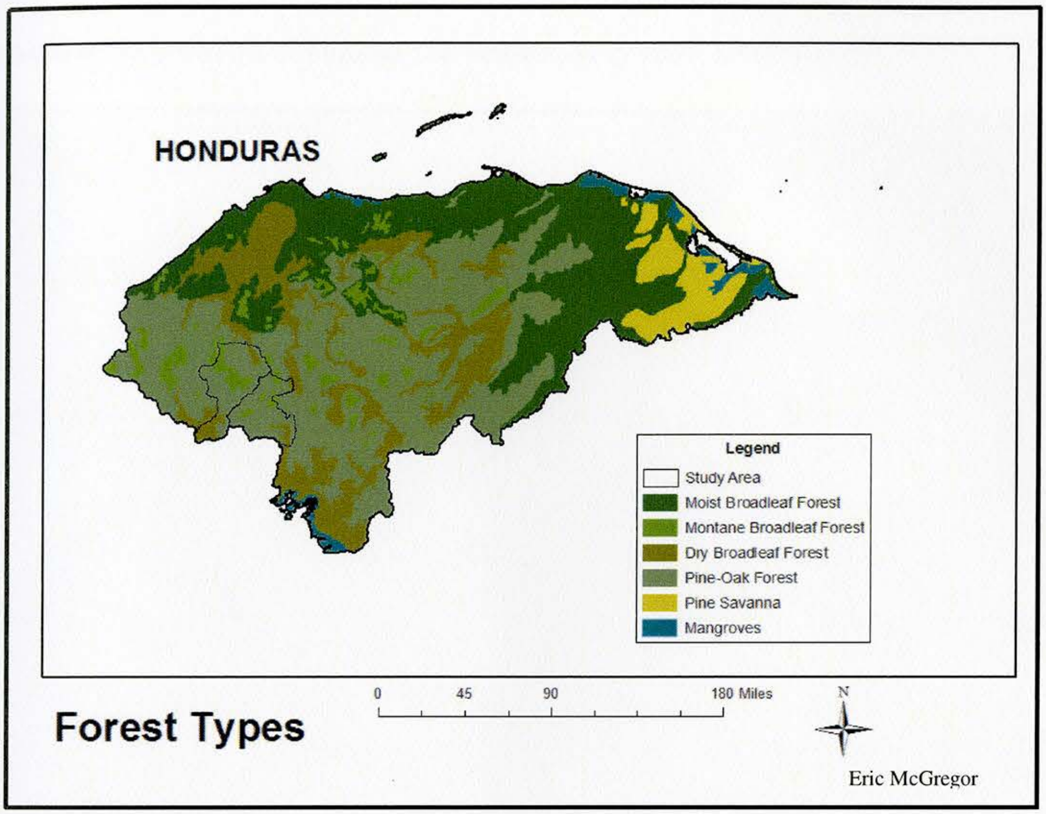


Figure 5. Map displaying prominent forest types throughout Honduras. Pine-oak, montane broadleaf, and dry broadleaf forests are found in the study area.

Aside from natural forest regimes, patches of agroforestry make up part of the forested landscape. Local residents maintain forest patches of pine, oak, and other species, which they use for lumber, cooking fuel, fence posts, and to provide income. Brady (2001) describes a type of "de facto" agroforestry where *guachipilin* (*Diphysa robinioides*) trees are grown in swidden agriculture plots, providing nitrogen to the soil, construction material, and material for burial site crucifixes. Other managed forests include those that are maintained to shroud shade-loving coffee varieties common to the study area (Figure 6). Bass (2006) describes forest types associated with coffee cultivation. Guama (*Inga* spp.) trees are among the most common shade providers, and are often grown mono-specifically (ibid). Other shade-coffee stands include larger varieties of tree species including pine (*Pinus* spp.), oak (*Quercus* spp.), guachipilin (*Diphysa robinioides*), and mimosa (*Mimosaceae*) to name a few (ibid).

Figure 6. A coffee plantation with various tree species providing shade, guama (*Inga* spp.) being the most prevalent. Young coffee plants are seen in the foreground. Taken on highway CA-7 near the town of Marcala. (Photo taken by author)

Along with forests, landscapes in the study area display various aspects of the swidden cultivation system. In general, the *tierra fresca* contains fertile soils that make it more suitable for farming than some of the lower-lying areas. However, *milpas* (swidden agricultural plots) are common throughout the lowlands and highlands (Figure 7). The swidden system plays an integral role in creating the patchwork-quilt landscape previously mentioned (refer to Chapter II for details on swidden techniques). In the study area the swidden system creates three distinct landscape features – milpa, *guamil*, and forest (Figure 7). These features represent various stages of the agricultural system. A milpa is a plot currently under production. *Guamil* is an agricultural patch that has been abandoned and is in relatively early stages of succession; often containing briars and ferns (Brady 2001). If an agricultural patch remains fallow for long enough it will return to forest. Eventually, Lenca farmers will clear these *guamil* and/or forest patches again, restarting the system. In order for this system to revitalize soil nutrients, plots must remain fallow until they reach a certain level of maturity. This length of time can depend on soil quality, slope angle, and local food demand (Brady 2001). In recent years, restrictions placed on forest clearing have led farmers to prematurely clear *guamil* plots (Brady 2001). This potentially prevents soils from proper regeneration.

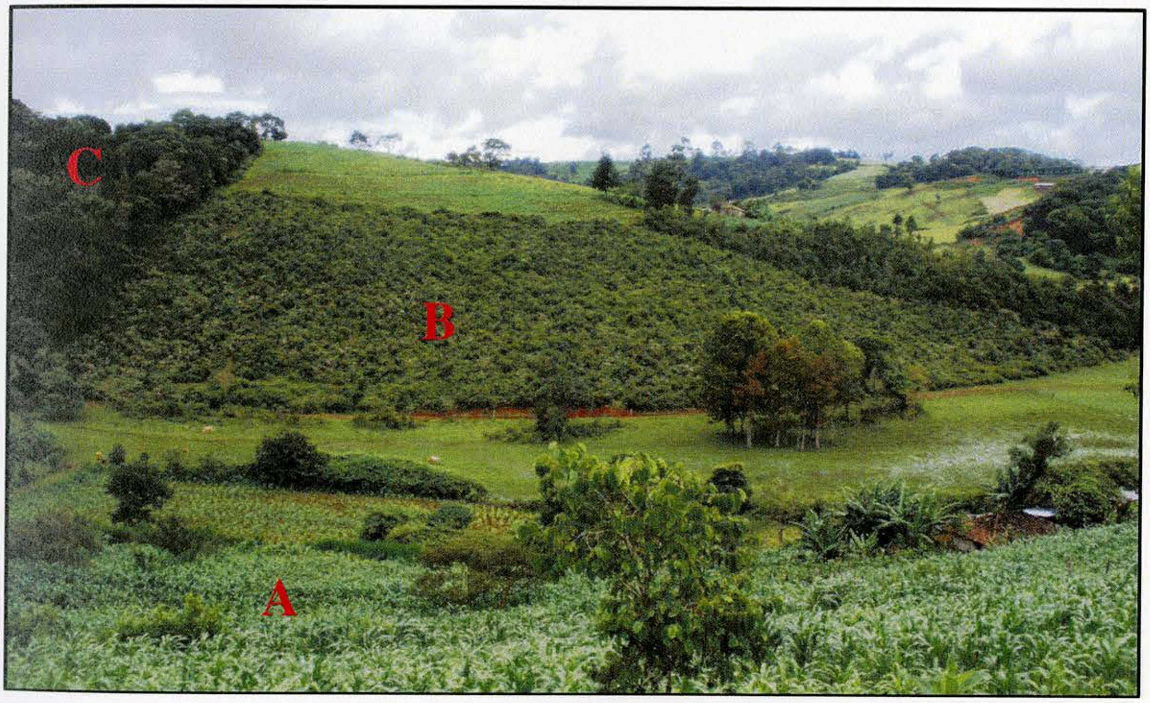


Figure 7. Stages of the swidden agricultural system. A) *Milpa* – a plot that is under production, with corn in this case; B) *Guamil* – early stages of secondary succession; C) Forest – a plot that has been fallow for several years. (Photo taken by author)

Corn, beans, and squash are the most common crops found in Lenca *milpas*, and are often intercropped in a single plot (Figure 8). The corn provides a stalk for the beans to climb. As a leguminous crop, beans have the ability to convert nitrogen from the air into a form that is usable through the soil. Similar to other areas of Middle America, squash is sometimes intercropped with corn and beans. Aside from simply producing food, squash plants can help prevent soil erosion. Wheat and potatoes, products of the colonial era, are occasionally found in *milpa* patches (West 1998). The Lenca also produce various vegetables, as well as bananas, apples, and peaches in dooryard gardens (plants grown directly around houses). The combination of natural forest regimes, agroforestry, swidden cultivation, and dooryard gardens creates a landscape wherein a number of forest types can be seen in a single view.

Figure 8. Corn and beans are often intercropped in the region. Here, beans are using the corn stalk as a pole to grow up. Photo taken by author.

CHAPTER IV

METHODS

This research uses repeat photography to assess forest conditions in the study area. Satellite image analyses are coupled with statistics to better understand the relationship between forest cover and coffee cultivation. Researchers have used a number of methods to study landscape change, including, but not limited to, participant observation (Tucker 2008), satellite and aerial image analysis (Redo et al. 2009), and repeat photography (Bass 2004, 2010).

Repeat Photography

Repeat photography is a method that is particularly useful in assessing local scale landscape dynamics. Originally used in the late 19th century to monitor alpine glaciers, it involves taking multiple photos of the same geographical locale in the most precise manner possible, at intervals of several years or decades, to provide information for evaluating change (Webb et al. 2010). Repeat photography allows the researcher to assess local patterns of landscape change in oblique landscape photographs that might otherwise not be seen in more distant and vertical aerial photographs or satellite imagery. Further, because it often requires extensive fieldwork, the researcher is able to gain subtle insights and a more complete cultural understanding of people's relationships with the land and concomitant landscape change (Bass 2010).

To date, a considerable body of research has relied upon repeat photography to assess land-use and land-cover change (Hastings and Turner 1969; Klett et al. 1984; Works and Hadley 2000; Clay and Marsh 2001; Nüsser 2001; Pickard 2002; Bass 2005; Clark and Hardegree 2005; Kull 2005; White and Hart 2007; Carré and Metailié 2008;

Heitmuller and Greene 2008; Hendrick and Copenheaver 2008; Michel et al. 2009; Nyssen et al. 2009; Webb et al. 2010). Webb et al. (2010) have recently compiled a text demonstrating current techniques in repeat photography and how they are applied to natural sciences. Some have demonstrated the potential for a quantitative approach, but this presents challenges that can be time intensive to overcome (Clay and Marsh 2001; Clark and Hardegree 2005; Hendrick and Copenheaver 2008; Michel et al. 2009; Nyssen et al. 2009; Hoffman and Todd 2010). Most of these studies have quantified vegetation change, many of them by analyzing photos' spectral qualities (Clay and Marsh 2001; Clark and Hardegree 2005; Hendrick and Copenheaver 2008). Hoffman and Todd (2010) demonstrate a quantitative approach in monitoring changes in various vegetation types in South Africa. Others have applied repeat photography – typically qualitatively – to cultural studies. Bass (2010) uses repeat photography as a way to better understand cultural contexts of land-use and landscape change in Honduras.

Photographs from the Robert C. West archives (West 1957), taken on a 1957 fieldtrip through Honduras, serve as the baseline data for the repeat photography component of this project. A portion of this archive was available to me in duplicate form in the Department of Geography and Geology at the University of Southern Mississippi. Approximately thirty photographs were chosen from a duplicated portion of the archive. Selection was based on the likelihood of finding sites and the proper qualities of the background landscape (i.e. large areas of visible rural property containing forest and/or agricultural patches) that allow for a fair assessment of notable areas.

I traveled to Honduras for four weeks during the summer of 2010 to seek out and re-photograph sites necessary for this analysis. I retook the 1957 photographs as precisely as possible with a 10-megapixel digital camera, paying close attention to vantage point, camera angle, azimuth, right/left, up/down alignment, and clockwise/counterclockwise rotation (Klett et al. 1984). Dr. West made notes on many of his photographs that provide general information such as geographical location and short descriptions of each photo. I used those notes, the field assistance of professors Joby Bass and Frank Heitmuller, as well as information from local residents and maps to relocate the scenes of these old photographs. Historical data and field observations help contextualize the changing patterns observed in the photograph pairs.

Forest Cover and Shade-Coffee Comparison

Satellite imagery was used to produce a land-cover map distinguishing forest from non-forest in the study area. Using data on the amount of land area under coffee production in each *municipio*, maps were generated to display areas with higher than average rates of cultivation (IHCAFE 2011). Ultimately, forest and coffee data were compared to look for a statistical relationship between the two.

A Landsat 5 TM image from March 2011 was downloaded through the USGS Earth Explorer interface (USGS 2011). The image selected was from Path 18/Row 50 (14° 27' 34" N, 87° 45' 07" W), and contained, in full, the departments of Intibucá and La Paz. The March image was chosen because it contained minimal cloud cover over the study area. This is technically during the dry season, which can produce error in the data because of the dry conditions of the foliage. However, error in this case would underestimate the amount of forest in the area. Further, many areas are at altitudes that do not have distinct dry seasons.

Initially, ERDAS Imagine 2010 software was used for image processing. An unsupervised classification was conducted using 15 classes and 20 iterations. I chose to do an unsupervised classification due to the small number of classes being used, and I felt it would save time spent in the field collecting training samples that would be required to do a supervised classification, enabling more time for the primary data collection – repeat photographs. The classified image was loaded into ArcMap 10 for further processing. A shapefile of *municipios* within Intibucá and La Paz was used to extract the study area from the classified image. Then, working within the study area, the classes in the image were aggregated. The original fifteen classes were reduced to three (forest, non-forest, and cloud/shadow). To make sure the classes were properly aggregated, the original satellite image (depicted as a false color composite) along with Google Earth (2006 imagery) were used for visual comparisons. Thirty sites were randomly selected in the classified image. These sites were then compared to the original image to make sure land-cover was properly classified. Google Earth was used in some cases for a higher resolution view of the land-cover. Notably, the Google Earth image was from 2006 which could produce some error. The cloud/shadow class was used as a way to omit cloud and shadow pixels from the analyses. The goal here was to have two land cover classes, forest and non-forest. The forest class includes areas that appear, in the satellite images (Landsat and Google Earth), to be covered by vegetation with a visible canopy. The non-forest class generally includes bare earth, grasslands, developed areas, and others that do not fall into the forest or cloud/shadow classes. The number of hectares in each class was then calculated by multiplying their pixel counts per *municipio* by .09 (1 pixel = .09 hectares) (NASA). All classes were summed to reach a total area for each *municipio*. From here, percentages of forest and non-forest were calculated. These data were then analyzed relative to data regarding land use and coffee production.

Coffee data for Honduras is available online through the Instituto Hondureño del Café (IHCAFE) (Honduran Coffee Institute) (IHCAFE 2011). The data used are from the 2008–2009 season, and include the number of coffee producers, as well as the area under coffee production. All data are at the *municipio* level. The areal measurements were converted to hectares from Honduran *manzanas*. The conversion used was 0.73 hectares to one *manzana*. From these data, the percentages of land in coffee production within each *municipio*, and the average number of hectares per producer were calculated. Notably, eleven of the 36 *municipios* were not included in the IHCAFE statistics. It is possible that these *municipios* do not produce coffee or do not have producers that are members of IHCAFE. Ultimately, 25 samples were used in statistical analyses involving coffee data. Further, the data are limited as they only include statistics from producers that participated in IHCAFE programs during the 2008–2009 season. This should not be a major problem for this research because it could only cause an underestimation of area in coffee production. However, because of this problem, it should be taken into consideration that coffee figures in this research could be understated.

It should be noted that the size, shape, and placement of each *municipio* could influence the outcomes of spatial statistics. For example, the *municipios* of San Isidro and Jesús de Otoro are 72 square kilometers and 414 square kilometers, respectively. San Isidro can have less land area in coffee production but a higher percentage than Jesús de Otoro. Coffee production in small *municipios* can be exaggerated. However, these data were the most obvious choice since they are often collected within such political boundaries.

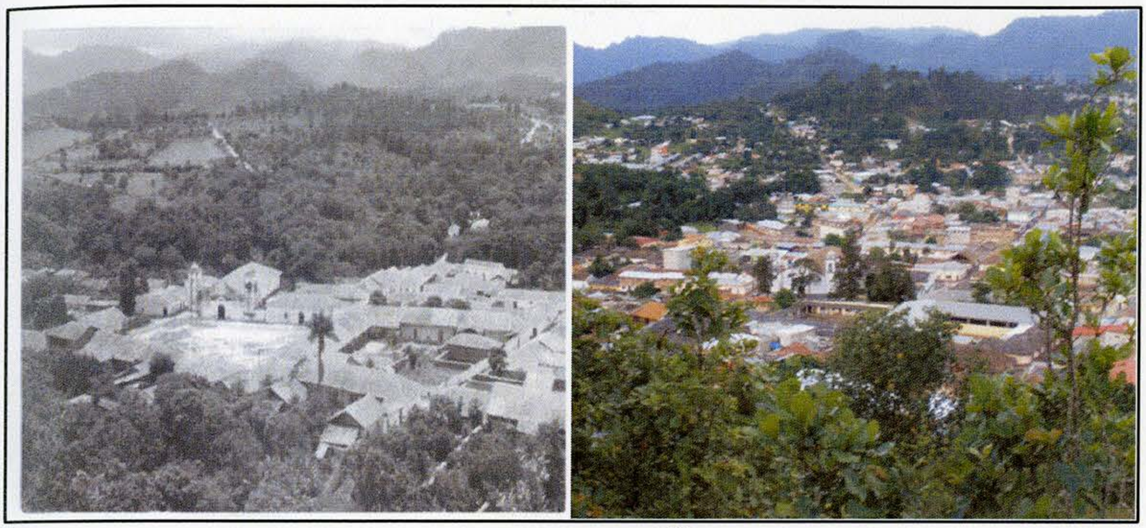
CHAPTER V

ANALYSIS

Repeat Photography

In July 2010, I took thirty photos from the Dr. West collection (West 1957) to replicate. Many of the photograph sites proved difficult to relocate since some roads were in different places in 1957, and Dr. West often travelled on mule trails. As a result, there were twelve photograph pairs used in this analysis. Each photo was visually analyzed, comparing those from 1957 to those from 2010. The photographs contain a variety of landscapes ranging from towns to rural hamlets. Each pair has the potential to inform about various aspects of changing vegetative conditions. I specifically focused on recognition of changes in the amounts of tree cover, and to detect/interpret the nature of such changes. The photo pairs display interesting land-cover changes since 1957. Some portray apparent growth in forests or trees, while others show obvious loss. Still others display changes that are too difficult to categorize and are considered inconclusive, as trees have been rearranged so that distinguishing changes in the amount can be difficult.

In many landscape change studies, classification schemes are developed to represent styles of change. In reference to landscape changes in the study area, I broadly employ the terms *tree increase, tree decrease,* or *inconclusive*. While it is possible that photo pairs could exhibit no noticeable change in tree cover, it is not the case for any of the pairs in this study, and is thus not a classification category. More descriptive categories will be used to specifically characterize the nature of tree cover increase. Most of the increases found in this study occur in the form of *reforestation*, *afforestation*, *dooryard gardens*, *settlement trees*, and *scattered tree cover*. *Reforestation* refers to patches of trees growing naturally on a landscape that has been deforested in recent years. Generally, reforestation describes an area that is undergoing secondary forest succession, such as a cultivated plot that is in fallow. Conversely, *afforestation* generally refers to the intentional planting of trees. In the case of this research, afforestation typically refers to trees that are grown for building material, fence post, or firewood. Trees found in the immediate vicinity of homes are referred to as *dooryard gardens*. These are common in the study area, and are comprised of various plants including fruit trees. Similar to *dooryard gardens* are *settlement trees*, which occur within villages but are generally not associated with a specific household. For example, the central plazas of many towns and villages contain shade trees. Lastly, *scattered tree cover* describes areas that are sparsely speckled with trees and display no definite pattern in arrangement. Notably, I employ a broad definition of *forest* that includes tree patches of various sizes, heights, densities, and species diversity. For more dispersed tree patterns the term *tree cover* is used over *forest*.

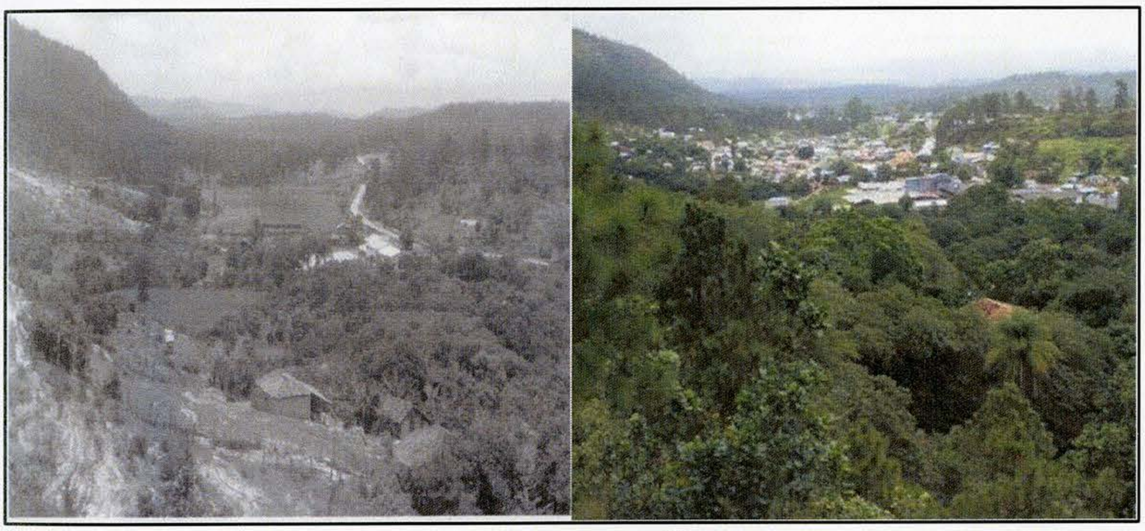


A. B.

Figure 9. Marcala, La Paz, Honduras.
A. (1957) View overlooking the town of Marcala, facing east (West 1957, H1-5).
B. (2010) This area has decreased in overall tree cover since 1957 due to urban development, however, dooryard gardens and settlement trees persist. (photo taken by author)

Figure 9 shows a photo pair looking over the town of Marcala. Overall this pair displays a *decrease* in tree cover. The most noticeable decline occurs around the center of the photo where primarily oak woodlands have given way to urban expansion (West 1957, H1-5). However, on the hill in the mid-to-background pine trees persist and appear to have increased over the fifty-three year period. An area in the mid-to-upper left of the photos has been converted from cultivated land to residential dwellings. This area shows an increase in tree cover, much of which can be attributed to *dooryard gardens* that have followed the pattern of residential land-use. Further, more trees appear among the buildings in town in Figure 9B, which are *settlement trees.* More trees are also apparent in the immediate foreground of the 2010 image, partially blocking the field-of-view. In all, this pair demonstrates a decline in tree cover, but illustrates how trees can sometimes follow patterns of development.

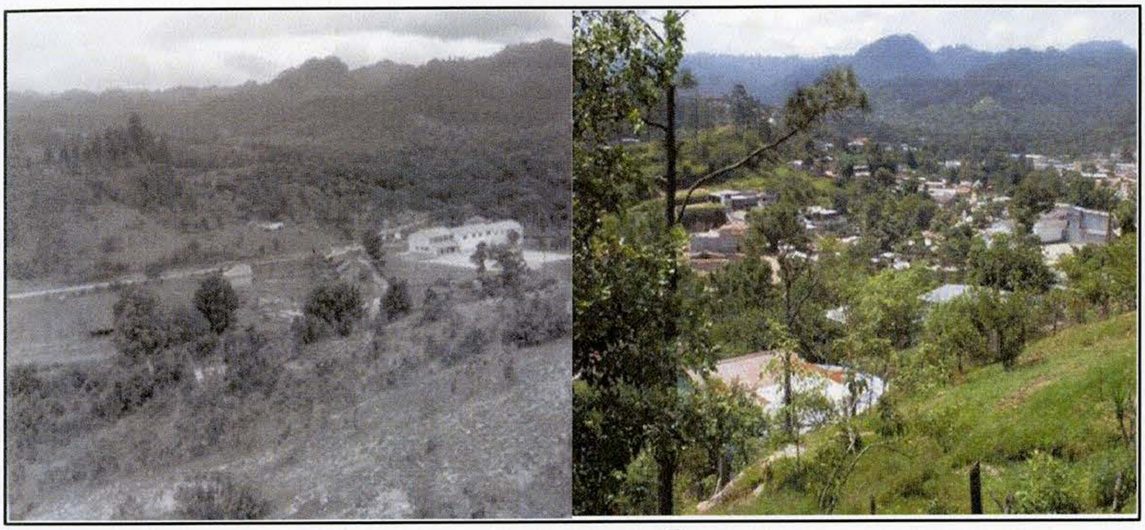
Figure 10 looks over a part of Marcala that has been developed since 1957. In Dr. West's notes on this photo he called this the "outskirts of Marcala" (West 1957, H1-6). In 2010, it is a formal part of the town. Near the center of Figure 10A is a coffee processing plant. The same one is present in Figure 10B. Dr. West mentions that coffee cultivation had recently been introduced into the area in 1957 (West 1957, H1-6). Records show that coffee was being produced there during the 1800s (Bonilla 1931). Today, the coffee industry is responsible for many of the land-use and economic changes taking place in this area.



A. B.

Figure 10. Marcala, La Paz, Honduras.
A. (1957) View looking north-northeast from Marcala. A coffee processing plant can be seen in the mid-ground near the road (West 1957, H1-6).
B. (2010) Tree cover appears to have expanded in areas of the photo, but overall it is too close to definitely state that tree cover increased. (photo taken by author)

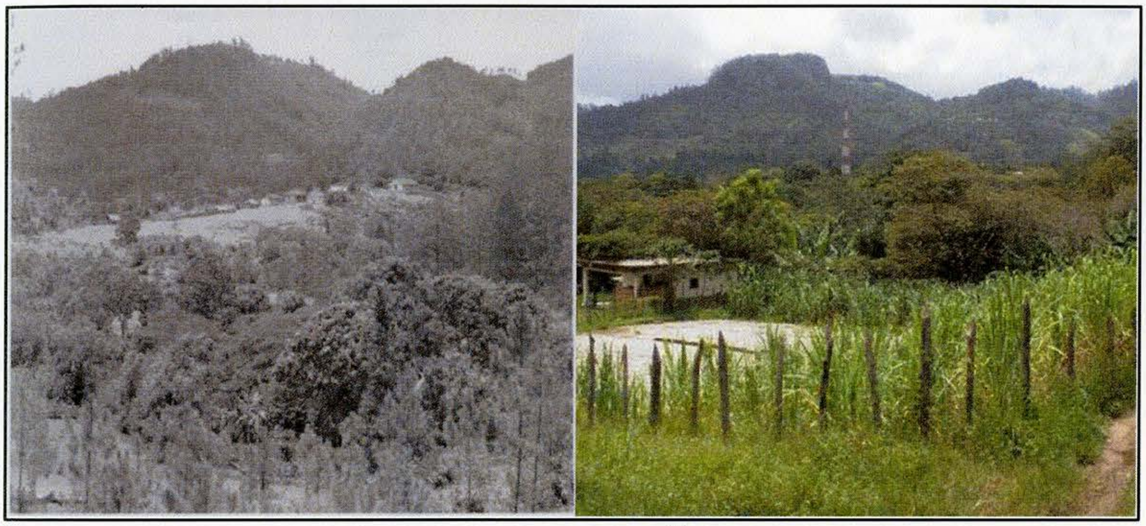
Observations of Figure 10 indicate that there could be an overall increase in tree cover. However, because it is hard to be certain, I consider it *inconclusive*. In the foreground reforestation has occurred, replacing pasture with pine-oak forest. These increases could be offset by decreases elsewhere in the photo, specifically in the background where details become distorted. Further, much development has taken place over the past fifty-three years on agricultural land. This appears to have left some forested areas intact, such as that on the right side of the mid-ground. Even in the developed areas in the background trees persist in the form of *dooryard gardens*. The variety of trees and other plants that are growing around the home in the foreground of the 1957 photograph illustrate the dooryard garden tradition as well as reforestation.



A. B.

Figure 11. Marcala, La Paz, Honduras.
A. (1957) A view facing southeast (West 1957, H1-13).
B. (2010) An overall decline in tree cover has taken place due to urban expansion. (photo taken by author)

Figure 11 is also looking over part of the town of Marcala. The coffee processing plant seen in Figure 10 can also be seen from a different direction on the mid-right of both photos in Figure 11. Although there is some new vegetation that appears in the immediate foreground of the 2010 image, there appears to be an overall decline in tree cover. Some of the forest on the mid-right side of Figure 11A has given way to urban development in Figure 11B. However, similar to the other pictures from Marcala, much of the development has taken place on areas that were already free of trees in 1957. On the valley floor, near the coffee processing plant, in the center of the photo such development has occurred. Interestingly, there appear to be as many, if not more, trees in that specific area now than were there in 1957. This area was difficult to classify in Figure 10. Using Figure 11, it could be argued that Figure 10 shows an *increase* in trees instead of *inconclusive*. Throughout this photo pair many trees persist within the developed landscape.



A. B.

Figure 12. Chinacla, La Paz, Honduras.
A. (1957) The village of Chinacla is visible in the mid-background. (West 1957, H1, 15-8)
B. (2010) Today, the village is no longer visible due to the canopy of a coffee forest in the mid-ground. Notice the concrete patio in the foreground used for drying coffee fruits. (photo taken by author)

Figure 12 is looking toward the village of Chinacla, La Paz, which lies just northeast of Marcala. In the 1957 photo the village is visible in the mid-background. A thick patch of forest has completely blocked the view of the village in the 2010 image. Although some young pines appearing in the foreground in 1957 were not present in 2010, overall this photo pair points to an increase in tree cover. Notably, the kind of forest in the 2010 image is grown to provide shade for coffee plants growing under its canopy. Shade-coffee cultivation is a common landscape feature in this area, and might involve intentionally planting specific tree species or selectively thinning an existing tract of forest to provide the proper coffee-growing conditions. In the foreground is a concrete patio used for sun-drying the coffee fruits after they have been picked.

A. B.

Figure 13. Azacualpa, Intibucá, Honduras.
A. (1957) Overlooking a *chagüite* (highland, poorly–drained valley), Llano de Azacualpa (West 1957, H6-8)
B. (2010) The background hill slopes display an increase in trees. This increase is due in part to the replacement of agricultural plots by trees. (photo taken by author)

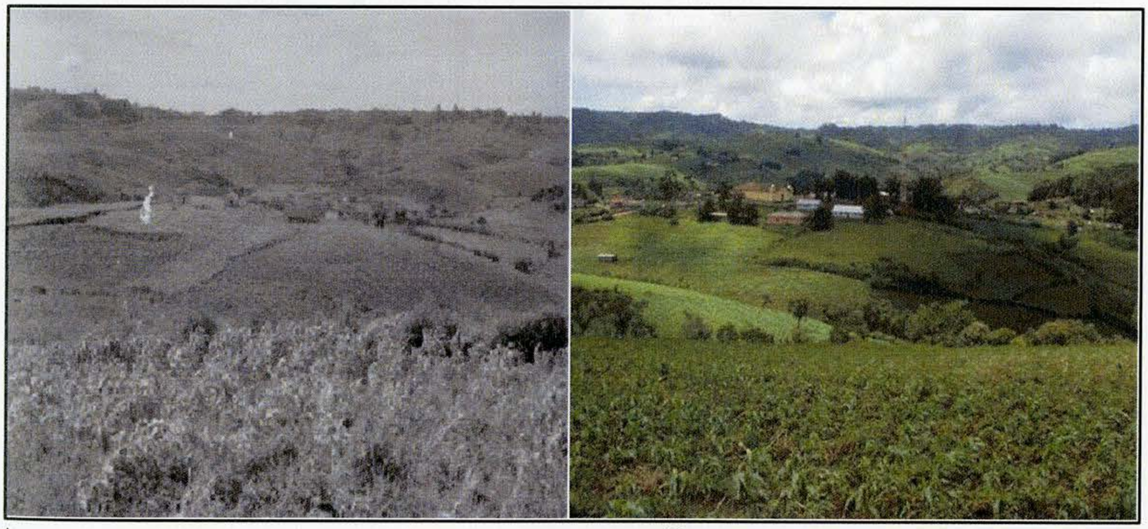
The photo pair in Figure 13 displays a slight decrease in tree cover in the foreground. However, a noticeable increase in forest cover on the background hillslopes points toward an overall increase over the fifty-three year period. Notably, the saturated soils of the *chagüite* is not conducive to tree growth. In 1957 a larger portion of the hillslopes were being used for swidden agriculture than in 2010. This is detected when comparing the background hillslopes in the left side of the images. Tree cover in the 2010 photo is more dense and less fragmented. Inaccessible road conditions during fieldwork did not allow a closer examination of the nature of the forests on these hillslopes, but inferences can be made by closely examining the photo pair and the surroundings that were accessible. The increase in tree cover can be attributed to a combination of reforestation of fallow agricultural plots, afforestation (agroforestry), trees along fence rows, scattered trees, as well as dooryard gardens. Young pine trees were observed in the area growing in small plots, purposefully planted.

A. B.

Figure 14. Azacualpa, Intibucá, Honduras.
A. (1957) Overlooking Llano de Azacualpa and agricultural fields on the lower slopes (West 1957, H6-9).
B. (2010) More trees occupy the background hill sides. Interestingly, agriculture seems to have migrated down-slope over the 53 year period. (photo taken by author)

The photos in Figure 14 were taken from the same location as those in Figure 13, only directed westward. Many of the landscape features found in Figure 13 can also be seen in Figure 14. There is an obvious increase in trees on the background hillslopes. Specifically, forest has increased on the upper slopes in the center-background of the image. In 1957 young trees were thinnly scattered across the slopes. In 2010 tree cover has become more abundant and dense on the upper hillslopes, where homes are interspersed among the trees. The lower hillslopes along with the basin floor, West notes, were used "almost entirely [as] pastures that support large herds of cattle, horses and mules" (West 1957, H6-9). These basins continue to support livestock, but it appears some agriculture has moved to the lower slopes and in some cases to the basin floor. In the foreground of the 2010 photo (Figure 14B) maize (corn) fields – in fallow and in production – are seen.

The down-slope migration of agriculture could reveal a reduction in the amount of land needed for grazing since 1957. Historically, these *chagüites* have been used to provide fodder for seasonal cattle migrations to markets in Honduras, El Salvador, and Guatemala. It is uncertain to what extent this occurs today. A reduction in the number of cattle in these annual drives could allow agriculture to shift from the upper slopes to the lower, leaving the higher slopes to be used for tree growth and settlements. Both Figure 14 and 15 show this shift in land use across time. Notably, the mid-ground of Figure 15A shows some agriculture on a lower slope in 1957 (surrounded by a wooden fence), but the immediate foreground has shifted from pasture to maize cultivation.



A. B.

Figure 15. Santa Elena, La Paz, Honduras.
A. (1957) View overlooking the village of Santa Elena (West 1957, H1, 16-2).
B. (2010) More trees occupy the present-day landscape as agroforestry, dooryard gardens, settlement trees, and trees along fence rows. (photo taken by author)

Figure 15 demonstrates an overall increase in trees, which occur as afforestation, fence rows, and scattered patches across the landscape. There are more trees surrounding the buildings in the center of the village in 2010 (center of photo), many of which are coniferous. A patch of woodlot mixed pine-oak trees can be seen in Figure 15B (right center) that was near nonexistent in Figure 15A. Much of the landscape in both images is dominated by cultivated land; maize is growing in the foreground of both images. The background of Figure 15B (difficult to see here due to sizing) is characterized by milpas and forest patches of various sizes. It was difficult to detect tree cover change in this area due to the picture quality of Figure 15A. Still, it appears that more trees were present in 2010 (Figure 15B). These trees are not large tracts of old-growth forest, but small patches dispersed across the landscape.

A. B.

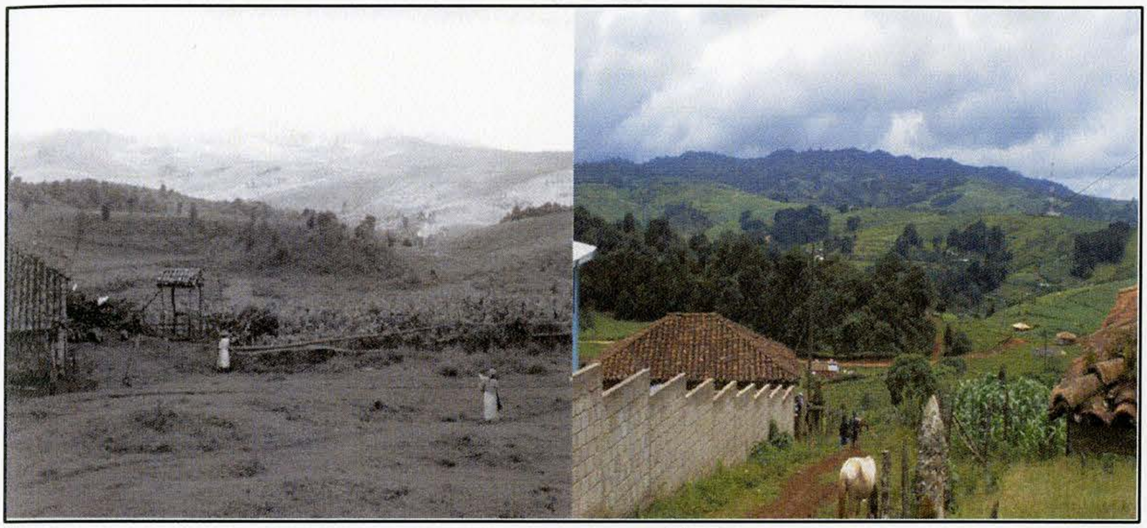
Figure 16. Santa Elena, La Paz, Honduras.
A. (1957) This view was taken in the village of Santa Elena (West 1957, H1, 16-1).
B. (2010) Today, trees occupy part of a village landscape that was devoid of trees in 1957. (photo taken by author)

Figure 16 shows an overall increase in trees. The most obvious are those around the buildings in town, but tree patches are also dotted across the background (left) of Figure 16B, which are not apparent in Figure 16A.

Figure 17 displays an increase in trees. Increases took place in the form of agroforestry, dooryard gardens, and trees along fence rows. The forest patches on the hillslope in the background (Figure 17B) are made up of oak (*Quercus*), pine (*Pinus*), and laurel (*Laurus*) species. Wood harvested from them is used for construction material, fence posts, and cooking fuel (Bass 2010). Houses are tucked in among the trees and milpas. In the foreground of Figure 17B coniferous trees are growing along a fence lining a dirt path. This area, along with the majority of the photograph, was devoid of trees in Figure 17A.

A. B.

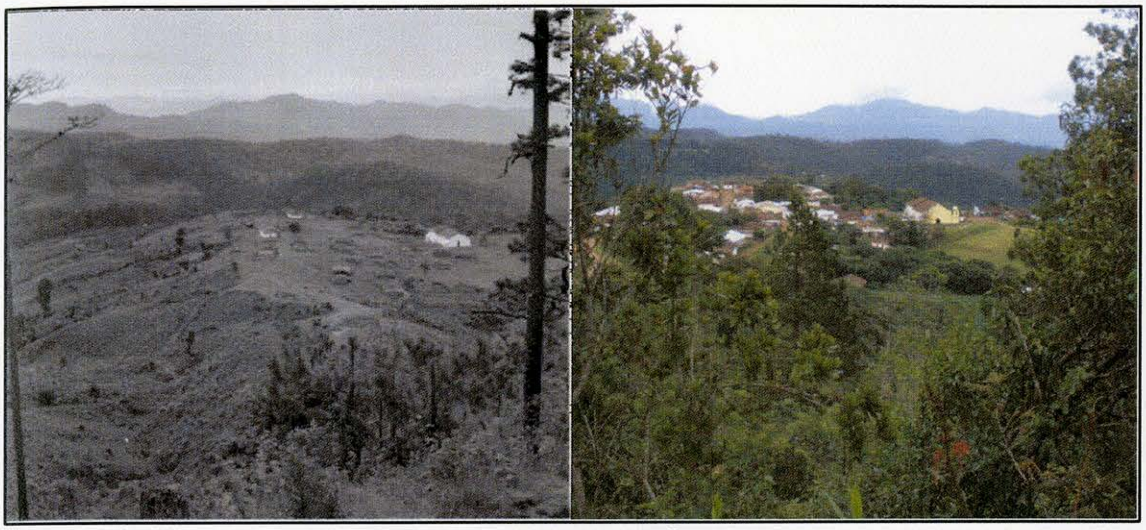
Figure 17. Yarula, La Paz, Honduras.
A. (1957) A view overlooking Llano Yarula where livestock area grazing. Only a few trees dot the landscape. (West 1957, H1, 16-5)
B. (2010) Forest patches surround homes in the background, providing people with lumber and fuel for cooking (Bass 2010). Coniferous trees line a fence in the foreground, a phenomenon that appears to be common in this area. (photo taken by author)



A. B.

Figure 18. Yarula, La Paz, Honduras.
A. (1957) A view from the village of Yarula. Much of the landscape is devoid of trees. (West 1957, H1, 15-9)
B. (2010) Forest patches, dooryard gardens, and *milpas* characterize the present-day landscape. (photo taken by author)

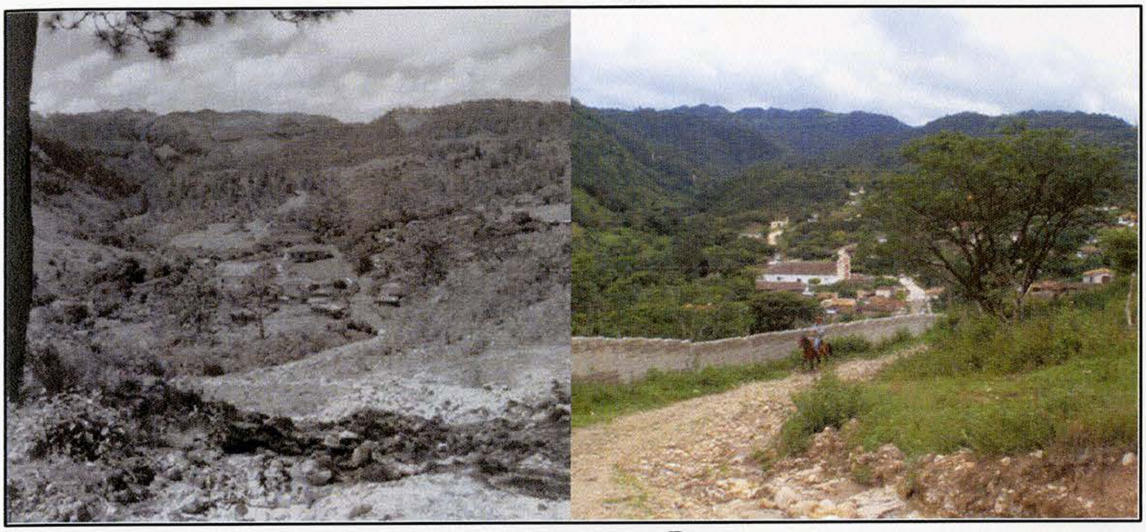
The view in Figure 18B is characterized by forest patches, dooryard gardens, and trees generally scattered across the landscape, most of which were not present in Figure 18A. The hill in the mid-ground of Figure 18A has a few scattered trees and is not under agricultural production like other areas in the image. The same hill in Figure 18B is covered by mixed forest containing oak (*Quercus*) and laurel (*Laurus*) trees. Looking across the *aldea* (hamlet) in the background (Figure 18B), many of the tree patches are associated with homes, either as dooryard gardens or agroforestry near houses. Along with trees, agricultural activity dominates much of the landscape in Figure 18B. Likewise, a *milpa* containing maize is present in Figure 18A (mid-foreground).



A. B.

Figure 19. Santa Ana Cacauterique, La Paz, Honduras.
A. (1957) A view overlooking the village of Santa Ana. Few trees exist directly around the village, and much of the nearby slopes are under agricultural production. (West 1957, H1, 16-8)
B. (2010) Overall tree cover has increased since 1957. Today, many trees cover the foreground, and although the settlement has grown, trees are integrated among the buildings. (Photo taken by author)

Figure 19 shows an increase in tree cover. Although the village has expanded since 1957, many trees are interspersed among the settlement. There does not appear to be a significant change in forest cover in the background across the photo pair. However, much of the mid-to-foreground has been reforested (Figure 19B), replacing some agricultural patches present in Figure 19A. Notably, Figure 19B appears devoid of *milpas*, whereas Figure 19A displays a predominately cultivated landscape.



A. B.

Figure 20. La Campa, Lempira, Honduras.
A. (1957) This view, overlooking La Campa, depicts trees thinly scattered throughout the village (center), and some clearings on the background slopes. (West 1957, H1, 18-4)
B. (2010) The hillslopes surrounding La Campa are densely covered with trees today, and although the village has grown considerably, tree are a prevalent part of the landscape within the village. (photo taken by author)

Despite the expansion of the village since 1957, forest and tree cover in La Campa have also expanded (Figure 20). Overall, more trees are present in town and the forests on the hillslopes are more extensive and thicker. It is difficult to define particular land uses in the 1957 image (Figure 20A), but the clearings in the mid-to-background are likely for agriculture and/or the extraction of forest resources. Tucker's (2008) extensive research in La Campa sheds light on forest conditions there and will be discussed in Chapter VII.

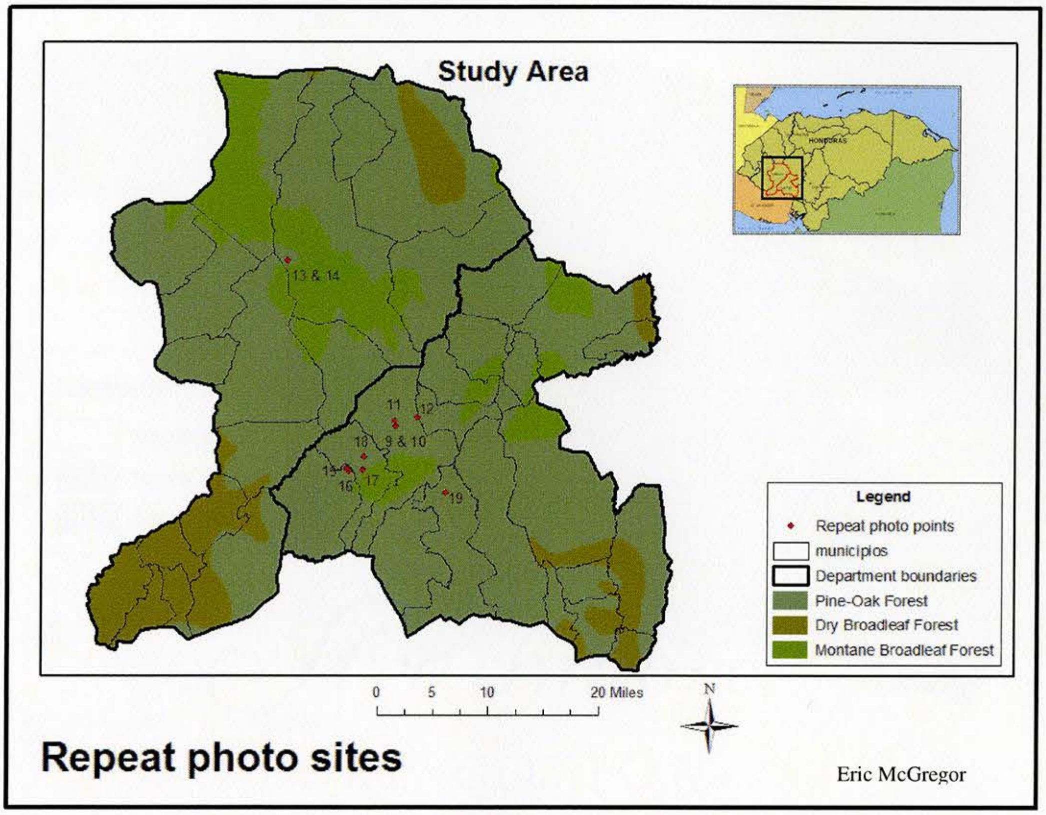


Figure 21. Study area showing photograph sites and major forest associations. Numbers correspond to Figure numbers. Photos that were taken from the same location but facing a different direction are listed together (e.g. 9 & 10).

Forests and Coffee Production

After compiling forest cover data from the satellite images (Figure 22) and coffee data from IHCAFE, statistical analyses were conducted to determine if a relationship exists between forest cover and coffee cultivation.

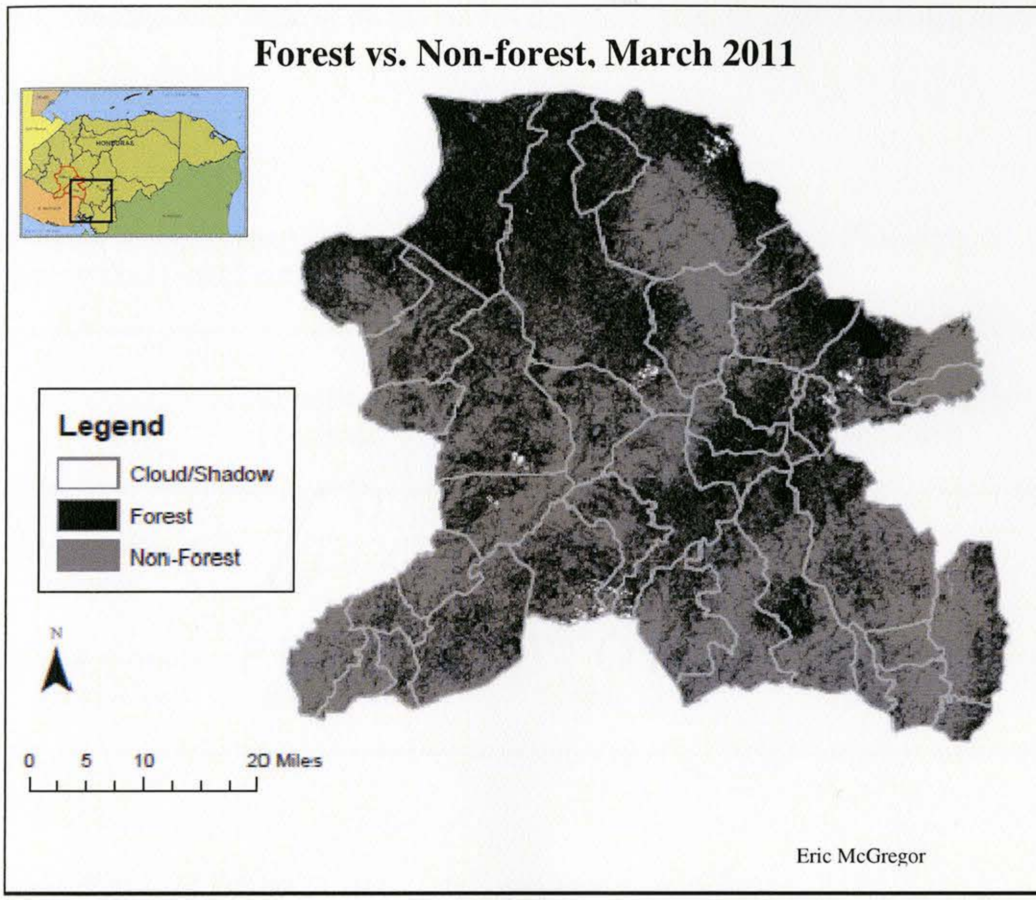


Figure 22. Land cover classification of study area derived from March 2011 Landsat TM imagery (USGS 2011).

Initially, *two sample difference of means* tests (t-tests) were used to check for differences in both forest cover and amount of land in coffee production between the two departments in the study area (Intibucá and La Paz). At a p-value of 0.86, the test showed no significant difference in mean forest cover between the two departments (Table 1). As a whole, the *municipios* of Intibucá had 46.6 percent of their land covered by forest, whereas thos in La Paz had a mean percent forest cover of 45.3 percent (Table 2). Together, Intibucá and La Paz had a mean percent forest cover of 45.9 percent, with the lowest *municipio* having 7.2 percent and the highest having 95.6 percent forest cover.

These percentages can depend on the size of the *municipios*, as well as the size of towns located within them.

Table 1

Independent Samples Test (T-Test for Equality of Means) on Percent Forest Cover between Intibucá and La Paz.

	Significance (2-tailed)	Mean Difference	Standard Error Difference
1. Equal variances assumed	.863	1.361	7.841
2. Equal variances not assumed	.864	1.361	7.872

Table 2

Group Statistics for Percent Forest Cover, Intibucá and La Paz.

Department	N (of *municipios)*	Mean forest cover (percent)	Standard Deviation	Standard Error Mean
1. Intibucá	17	46.661	24.325	5.899
2. La Paz	19	45.300	22.720	5.212

Like percent forest cover, a *two sample difference of means* test shows no significant differences (.073) in percent of area in coffee cultivation across the departments (Table 3). In Intibucá, 4.45 percent of land area is used to produce coffee, while 9.75 percent is used for coffee in La Paz (Table 4). Notably, coffee data was not available for all *municipios*. Eleven of 17 had data available for Intibucá and 14 of 19 for

La Paz. Since no significant differences existed in forest cover and coffee cultivation across departments, these variables were examined in terms of the entire study area (i.e. both departments combined).

Table 3

Independent Samples Test (T-Test for Equality of Means) on Percent of Land Area under Coffee Production between Intibucá and La Paz.

	Significance (2-tailed)	Mean Difference	Standard Error Difference
1. Equal variances assumed	.073	-5.296	2.821
2. Equal variances not assumed	.058	-5.296	2.648

Table 4

Group Statistics for Percent of Land Area under Coffee Production, Intibucá and La Paz.

Department	N (of *municipios)*	Mean coffee cultivation (percent)	Standard Deviation	Standard Error Mean
1. Intibucá	11	4.456	4.763	1.436
2. La Paz	14	9.753	8.326	2.225

I conducted a correlation test to look for a potential relationship between forest cover and coffee cultivation. Only 25 of 36 *municipios* were used due to the availability of coffee data. A significance level of .016 indicates that a relationship exists between the variables (Table 5). The Pearson's correlation coefficient (.475) suggests that the relationship is positive, as one of the variables increases so does the other (Table 5).

To get a more complete understanding of this relationship, I performed a bivariate regression test. Percent coffee served as the independent variable and percent forest as the dependent variable. The regression showed the same significance level as the correlation (.016). The r-squared value (.226) (Table 6) suggests the weak positive relationship, 22.6 percent of the variance in percent forest cover can be explained by percent coffee. Figure 23 displays the nature of the relationship between the two variables with a least squares regression line.

Table 5

Correlation between Percent Coffee and Percent Forest.

Land Cover		Percent Coffee	Percent Forest
1. Percent Coffee	Pearson Correlation	1	.475
	Sig. (2-tailed)		.016
	N (of samples)	25	25
2. Percent Forest	Pearson Correlation	.475	1
	Sig. (2-tailed)	.016	
	N (of samples)	25	36

Table 6

Bivariate Regression

R	R Squared	Adjusted R Squared	Standard Error of the Estimate
.475	0.226	0.192	16.766

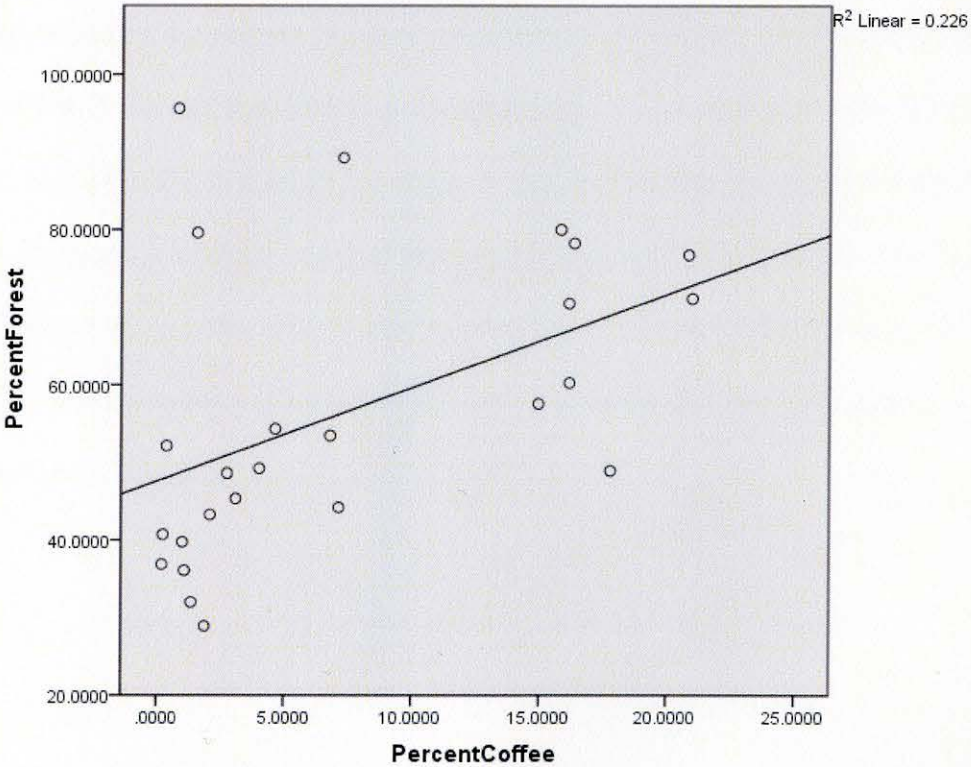


Figure 23. Least-squares regression line showing positive relationship between forest and coffee.

I also conducted correlation and bivariate regression tests on percent non-forest and percent coffee to verify the positive relationship between forest and coffee. As I suspected a negative relationship exists between percent non-forest and percent coffee. Indeed, this supports the positive correlation between forest cover and coffee. The significance level (.015) confirms the significance of the relationship and the Pearson's coefficient (-.482) shows the negative correlation. Furthermore, the r-squared value (.232) from the regression analysis suggests that 23.2 percent of the variance in non-forest cover can be explained by percent coffee.

Spatial statistics were used to put the previous findings into a geographic perspective. The *Spatial Autocorrelation (Moran's I)* tool in ESRI ArcGIS 10 was used to see if forest cover was dispersed, clustered, or random among *municipios*. This test was based on the percent of forest cover in each *municipio*. The significance value (.000003) showed that there was statistical significance; forest cover is not random (Figure 24). The z-score (4.66) suggests that forest cover is clustered (Figure 23). Using a 95 percent confidence interval this z-value falls well outside of the statistically random range (-1.96 to 1.96). The *Moran's Index Score* (.51) also suggests spatial clustering. This index outputs a value between -1 and +1, where -1 is perfectly dispersed and +1 is perfectly clustered.

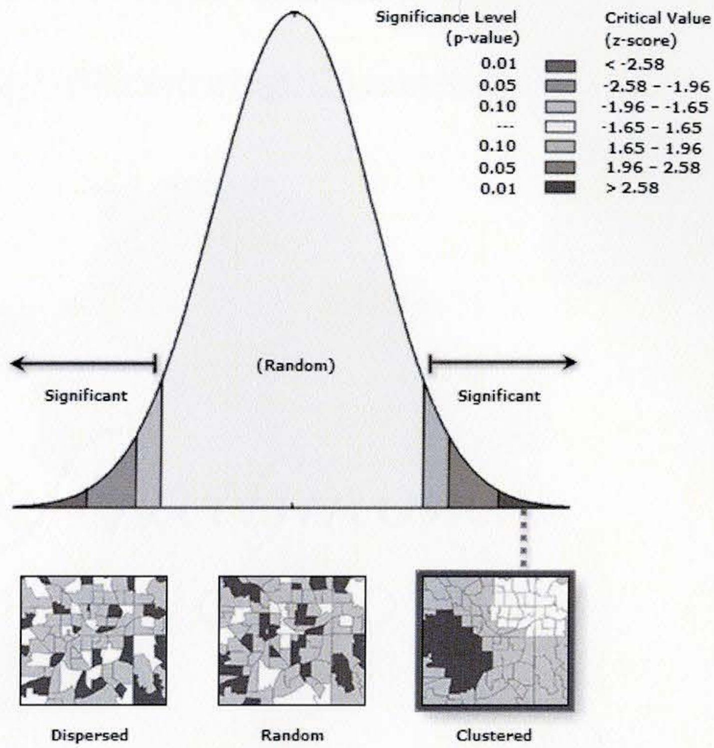


Figure 24. Spatial Autocorrelation (Moran's I) output indicating significant clustering. (figure derived from ESRI ArcGIS 10)

To visually support the spatial autocorrelation test I used the *Cluster and Outlier Analysis: Anselin Local Moran's I* tool in ArcGIS. This test outputs p-values, z-scores, and test statistics for each *municipio*. This function tests the percent forest value for each *municipio* against one that would be expected in a random distribution. Clusters of high values and low values are displayed (Figure 25). *Municipios* with statistically significant amounts of forest or non-forest are highlighted (Figure 25).

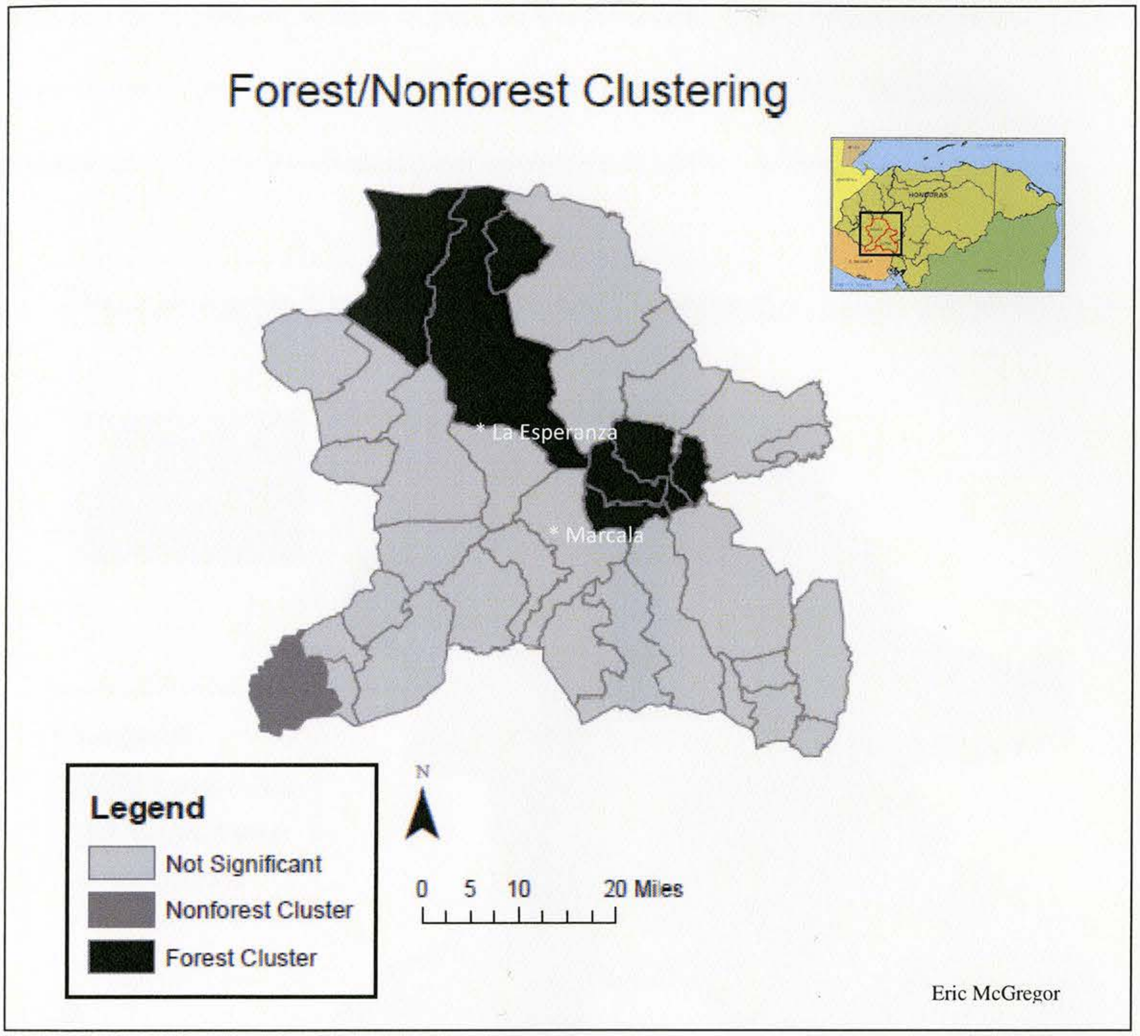


Figure 25. Map of Cluster and Outlier Analysis in Inibucá and La Paz, Honduras. Areas displayed in black show significant forest clustering. Major towns are labeled in red.

To compare forest clustering with coffee cultivation, I constructed a map that displays *municipios* with land area of coffee cultivation higher and lower than the mean (7 percent) (Figure 26). Five *municipios* share an above-average amount of coffee and significant forest clustering as tested using *Moran's I*. That is, 45 percent of the *municipios* that have an above-average percentage of land in coffee production also have a significant clustering of forest cover. Only two *municipios* that have significant clustering of forest cover do not have an above-average percentage of coffee production.

This can be explained, at least in part, by the elevation. These two *municipios* correspond to montane forests that are found at higher elevations (Figure 21). The climatic conditions at these elevations are not conducive to coffee cultivation.

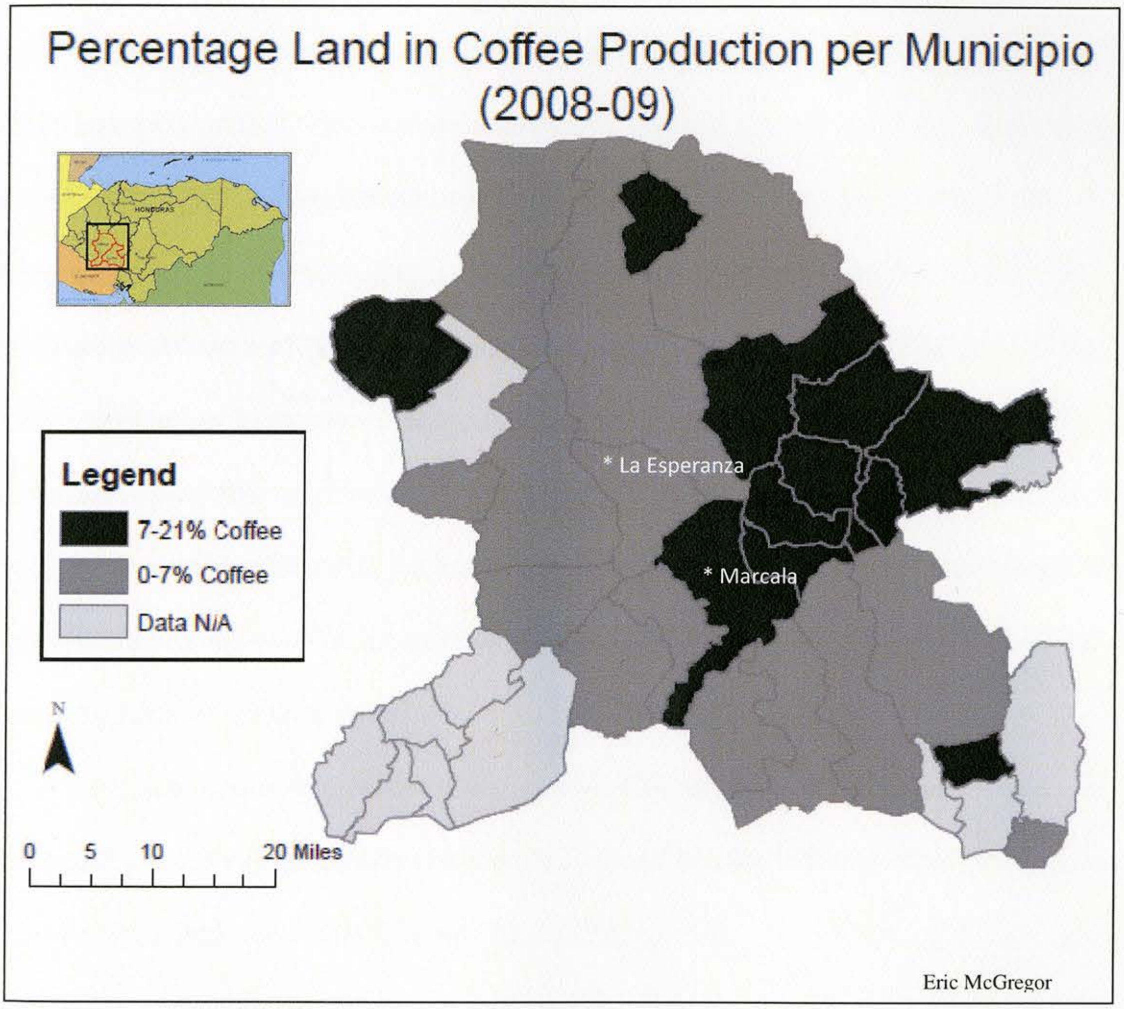


Figure 26. Percentage of land used for coffee production in Intibucá and La Paz, Honduras. *Municipios* with above average amounts of coffee production are shaded black. Majors towns are labeled in red.

CHAPTER VI

RESULTS

Repeat Photography and Forest Transition

As a whole, the photo pairs illustrated that more trees are on the landscape now than were in 1957. Nine of the twelve photo pairs displayed an *increase* in trees over the fifty-three year period. Two showed a *decrease*, and one was *inconclusive*. Interestingly, even in photo pairs that exhibited overall decreases in tree cover, some areas in the images displayed more trees (Figure 9). Notably, the two photo pairs with a decrease occurred in the town of Marcala, the most urban area in the photos. In Marcala, since 1957 land-use has been rearranged so that some forests were converted to urban land uses, and some pasture and/or cropland have been turned to residential areas. Figure 10 – rated *inconclusive* – illustrates such a scenario. Interestingly, some areas that turned from agricultural to residential zones exhibited more trees, which typically came in the form of dooryard gardens (Figures 9 and 10).

All nine photo pairs where tree cover proliferated were in rural areas. Trees increased in rural village centers (Figures 15, 16 and 19), as well as on surrounding hill slopes and throughout *aldeas* (Figures 13, 14, 17, and 18), even though most areas appear to be more densely populated in the 2010 photographs. In village centers trees dot the landscape around buildings. Moving out of the centers, variously sized tree patches occur along fence rows, as reforested and afforested areas, dooryard gardens, and irregular patches in pastures and *milpas*. Further, shade-coffee production creates a unique forest association that is common in the study area (Figure 12).

These landscape-change patterns have the potential to represent how forest transitions are currently taking place in areas of Latin America, and perhaps elsewhere in the developing world. Literature has pointed out pathways that lead to forest transitions (Farley 2010; Lambin and Meyfroidt 2010; Rudel 1998). I have selected five pathways from recent forest transition research through which to assess changes in tree cover in the photo pairs. These include forest scarcity, economic development, state forest policies, globalization, and smallholder tree-based land-use intensification (smallholder intensification). Pathways for each photo pair are tabulated in Table 7. Notably, multiple pathways can exist for a single pair.

The *forest scarcity* pathway occurs as people recognize limits of forest resources and begin to preserve and/or grow more trees. This pathway can be difficult to recognize by observation alone and most often requires interviewing local people. Notably, more of the photo pairs may fit into this category than Table 7 displays. Figure 17 is one example of how this pathway might appear on the landscape. These plantations are related to people's responses to dwindling forest products, and show trees that are being grown for fence posts, as well as for construction material and firewood for cooking (Bass 2010).

The *economic development* pathway occurs when land is abandoned as farmers move to urban centers in search of economic opportunity, leaving the countryside to forest regeneration. However, in Figure 9 this pathway is not seen as a rural landscape of abandonment and subsequent forest regeneration. Rather, it depicts an area in town that has seen population growth – likely from rural-to-urban migration – as well as an increase in trees on the land. Instead of illustrating areas of rural abandonment, the destination of some rural-to-urban emigrants is revealed. In a sense, it is a view of the reverse side of the *economic development* pathway. The implications of this pathway could be twofold in this case. Trees increased on the land the emigrants are currently occupying in town, but they could have also increased in the areas they abandoned.

One of the most difficult pathways to recognize is the *state forest policy* pathway. This refers to areas that exhibit an increase in trees due to governmental policies. The one photo pair that was placed in this category was taken in La Campa, Lempira (Figure 21), where extensive research has been conducted by Catherine Tucker (Tucker 2008). She found that governmental policies led to forest increases in the area (ibid). Trees in other photo pairs could possibly be linked to state policies; however, drawing such conclusions from repeat photography alone is not feasible.

The *globalization* pathway refers to ways that international ideas and economics contribute to forest increases. This may include input from international NGOs, or ties to global markets. Figure 12B demonstrates the impacts of economic globalization on the landscape, as it displays a coffee forest that was not present in 1957. This reflects an increase in market participation (IHCAFE 2011). In recent years, Honduras has increased the amount of coffee it exports, with Germany and the United States making up its two largest markets, respectively (U.S. Embassy 2008). Unlike most Central American nations, much of Honduras' coffee production takes place on small plots of less than 30 hectares, similar to that seen in Figure 12B (ibid).

Smallholder tree-based land-use intensification is a catch-all category, and generally refers to local-scale (individual- or community-level) tree plantations and dooryard gardens. Every photo pair displayed some type of smallholder intensification.

Indeed, it can be closely related to the other pathways. In other words, forest scarcity or state policies may drive individuals or communities to grow more trees. International organizations can influence people's perceptions about what is environmentally "good", and instill particular conservation ethics that lead to more trees on the land. (Sundberg 2003; Bass 2010). Again, many shade-coffee plantations in Honduras are small-scale operations and could fit well within this category.

Table 7

Pathways to Forest Transition Associated with Repeat Photos in Honduras.

Photo Pair	Forest scarcity	Economic development	State forest policy	Globalization	Smallholder intensification
1. Figure 9		**X**		**X**	**X**
2. Figure 10		**X**		**X**	**X**
3. Figure 11		**X**		**X**	**X**
4. Figure 12				**X**	**X**
5. Figure 13					**X**
6. Figure 14					**X**
7. Figure 15					**X**
8. Figure 16					**X**
9. Figure 17	**X**				**X**
10. Figure 18	**X**				**X**

Table 7 (continued).

Photo Pair	Forest scarcity	Economic development	State forest policy	Globalization	Smallholder intensification
11. Figure 29		**X**			**X**
12. Figure 20			**X**	**X**	**X**

Shade-Coffee

While this research does not present conclusive evidence as to how much forest expansion can be attributed to coffee forests, it does provide evidence pointing to the importance of shade coffee as a factor in reforested landscapes in the region.

The statistical results support a relationship between forest cover and coffee. The first statistical tests showed that neither percent forest cover nor percent coffee changed significantly between departments. From here, the study area was treated as a single unit rather than two departments. The correlation and regression supported a positive relationship between forest cover and coffee. This finding was then supported with spatial statistics. These tests showed that forest cover in the study area is significantly clustered in five *municipios*. A visual comparison of Figures 25 and 26 helps illustrate the relationship between forest cover and coffee production.

The town and *municipio* of Marcala (Figure 26) is an important center for coffee production and processing. It is of little surprise that nearby *municipios* display a concentration of above-average coffee production (Figure 26). Notably, some of the same *municipios* have a significant amount of forest cover as well (Figure 25). Marcala itself, however, does not show a significant amount of forest cover. This is because the actual town, which is counted mostly as non-forest in the classified image, encompasses a significant portion of the *municipio*.

These findings reinforce a relationship between forest cover and coffee cultivation. Furthermore, they are sensible when placed in the context of land-cover change research that has found notable connections between forest cover increase and coffee production. The consistencies between the findings here and those from others (Bass 2006; Redo et al. 2009), strengthens the argument that coffee production is contributing to forest resurgence in western Honduras. Bass (2006) found an increase in forest cover around the town of Marcala between 1954 and 1992. Some of this increase was associated with shade-coffee (Bass 2006). Building on this discovery, this research indicates a relationship between coffee cultivation and forest cover around Marcala, as well as other areas in the region. Further, it displays *municipios* where this relationship is significant.

CHAPTER VII

DISCUSSION

All of the photographs in this project display cultural landscapes. By comparing photographs from two different time periods changes in the cultural landscape can be detected. Trees serve as the focal point of this project, but are notably only a single component of landscapes that are often complex. Interestingly, tree cover seems to be expanding in the study area. However, types of tree expansion occurring cannot always be equated to dense forest expansion.

People arrange and rearrange landscapes in culturally specific ways. In many Latin American landscapes, large-scale deforestation has and is occurring for various reasons. Conversely, some Latin American landscapes are undergoing reforestation. The factors that contribute to this phenomenon are often complex and intertwined. In western Honduras, researchers have found landscapes that are experiencing such forest transitions (Bass 2006; Southworth and Tucker 2001). This research produced similar findings through repeat photography. Further, satellite image and statistical analyses helped elucidate the influence that coffee production might exert in forested and reforested landscapes.

Much of the tree expansion in the study area is taking place around homes, among settlements, and in small woodlots. These trees can be seen as a reflection of many Hondurans' continued reliance on forest resources. In the rural mountains of western Honduras most of the trees patches on the land serve a purpose. Trees around homes often produce fruit, shade, or serve medicinal purposes (West 1998). Woodlots produce fuel for cooking, construction materials, fence posts, or may be a reflection of the crop fallow cycle (secondary succession). Large tracts of trees may produce lumber for logging industries. In towns, it is typical to find trees providing shade around buildings or in plazas. Interestingly, many forests are thriving in the study area due the production of shade-loving varieties of coffee. Combined, these tree arrangements suggest that a forest transition will likely appear differently in Honduras than those that have occurred in other countries. Looking at the repeat photographs, it appears that the dominant pattern of tree expansion in the study area is small-scale and dispersed. Trees are scattered across the landscape in relatively small patches. While Honduras has implemented large land set-asides like national parks and forests – following conservation policies of the United States and European nations – they have been met with opposition from local people who continue to rely on the land for their livelihoods.

Patterns of forest transition are being driven by a complex network of factors. Forest transition theory suggests that economic development prompts people to move from rural areas into towns or cities in search of more stable income and access to amenities. In the context of tree expansion, the implications of the economic development pathway can be twofold. On one hand, as people abandon agricultural land in rural areas secondary forest succession can occur, assuming the land is not put to use in another way by others occupying the area. Secondly, the cultural tradition of dooryard gardens is transplanted into towns, potentially expanding tree cover therein. This second phenomenon was seen in some of the repeat photographs that were taken in towns. Interestingly, many of the rural sites in the study area did not appear to be landscapes of abandonment, but quite the opposite as many of the landscapes appeared to serve multiple functions for both subsistence and market-oriented production (e.g. pasture, cropland, agroforestry). This could be due in part to growing populations in both rural and urban areas since 1957 (population data could not be confirmed due to lack of updated and reliable census data).

Tree patches of various sizes characterize many parts of the rural landscape, and point to people's continued need for forest resources. The greater number of these patches in 2010 than in 1957 could reflect people's response to forest scarcity. Notably, if population rose over the 53 year period the demand for forest products would have likely increased as well.

Economic globalization has also contributed to changing forest conditions in the study area. Specifically, shade-coffee production appears to be playing an important role in maintaining current forests and even increasing forest in some areas. With the help of institutions like IHCAFE and assuming international coffee markets remain relatively stable, coffee forests will likely increase in the future. Many Hondurans have integrated subsistence and locally-based economic activities with coffee production for global markets (Tucker 2008). Participation in global coffee trade does not come without risks, as many Hondurans certainly remember from the coffee crisis that occurred from 1999–2003 when supply far exceeded demand and prices plummeted. As indicated by remittance statistics, many people participate in alternative ways to make cash.

International remittances play a large role in the Honduran economy. In 2009, $2.8 billion in international remittances were received by Hondurans (U.S. Department of State 2011). This accounts for about one-fifth of Honduras' GDP (ibid). In Intibucá, over 70 community projects, including those bringing electricity and drinking water, have been funded by international remittances (Endo et al. 2010). Additionally, remittances have funded 11 percent of businesses in the department capital, La Esperanza. The role of cash remittances can have important implications on landscape conditions, as families might rely more on cash to buy the things they need instead of using the land to produce them.

Diversification of livelihood strategies is one way that many people cope with market fluctuations. Some farmers also intentionally leave some of their land out of coffee production so they can increase the production of other crops if they deem it necessary (Tucker 2008). In La Campa, Tucker (2008) found that farmers typically only had about 28 percent of their land in coffee production. Notably, this percentage could be much higher in areas that have a longer history of market-oriented coffee production. Future research on these types of land use tendencies has potential to help explain amounts of forest cover.

Fluctuations in the coffee market can drive forest transformation in various ways. Forest expansion may occur if plantations are abandoned during times of crisis. However, deforestation could occur if people respond to crisis by clearing their plantations to make room for subsistence or other market-oriented crops. Further, some farmers might respond by clearing older fallows to plant crops, also resulting in deforestation. Obviously, these forests can be very dynamic. Their existence depends on a variety of factors, all of which pertain to economics. They are not pristine forests that have been set aside because of their beauty or ability to sequester carbon, and are thus not protected as such. While they do have some ecological significance, they are indeed market dependent. In the context of forest transition, special consideration should be given to forests that thrive because of specific economic activities. These forests fluctuate, in terms of size and distribution, with the dynamics of the market. This research outlines such forests (shade–coffee forests). It indicates areas where coffee cultivation and forests could be related. Further research should benefit from examining traits that are unique to the areas where the coffee/forest relationship is significant. These traits could then be compared with those from *municipios* that have a considerable amount of forest cover but not coffee. This type of comparison can help to understand land use in different areas.

CHAPTER VIII

CONCLUSION

Geographers have a long history of studying the human-environment interface. This research embraces that tradition. Everyday people around the world interact with the natural environment, directly or indirectly. In the rural mountains of western Honduras these daily interactions translate to a cultural landscape wherein people often work directly with the land. These landscapes reflect subsistence as well as economic activities, both of which rely on the usage of land-based resources, including trees. In general, this study set out to understand how people in western Honduras interact with these resources, specifically trees. It sought to shed light on changing forest conditions, looking for expanding or contracting tree cover in particular.

Repeat photography served as the primary platform for analysis, complemented by satellite image analysis and spatial statistics. All have their advantages and limitations. With photographs from only two years (1957 and 2010) this method does not detect trends or fluctuations in forest conditions over time. Was there a single gradual increase over the 53–year period? Or was there a more dynamic temporal pattern, characterized by peaks and lulls in tree cover? Repeat photography is further limited as it captures only a small portion of the Earth's surface, leaving much outside the range of analysis. However, this can be advantageous when examining local-scale conditions. On the other hand, detecting landscape conditions for a large area can be accomplished with relative ease using satellite imagery techniques. These techniques can collect a seemingly more complete inventory of landscape features than that offered by repeat photography, such as that provided by the coffee and forest cover component of this study. Notably, these techniques are limited by the error introduced when reducing a complex landscape to only a few categories on a map. And if not coupled with extensive fieldwork, many valuable insights are missed. Inherently, repeat photography exposes the researcher to the unique land-uses that shape particular landscapes, and offers a unique perspective through examining countless historic photographs throughout the research process.

Repeat photography clearly demonstrates tree expansion on landscapes in western Honduras. That is not to say that deforestation is not still a significant threat. Additionally, this study found that some of these increases can be attributed to coffee cultivation. Nonetheless, the status of a national-level forest transition in Honduras remains unclear. It is apparent, however, that certain land use activities are leading to tree and forest expansion at local scales. Some of these activities are subsistence related, while some are intrinsically economic. Still others are related to conservation or government policies.

This research does not provide a complete understanding of the many complex factors that drive forest transformation. Indeed, to approach a complete understanding would require a more in-depth, mixed methods technique. Nonetheless, by viewing changes found in the repeat photos in a context of forest transition theory, this study was able to suggest drivers of local–scale landscape change. Further, it shines light on the intricate ways that landscapes are transforming in part of the rural developing tropics in the 21st century.

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